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INFRARED SATELLITE DATA FROM THE FIRST COASTAL OCEAN DYNAMICS E--ETC(U)
JUL 81 K A KELLY N00014-75-C-0300
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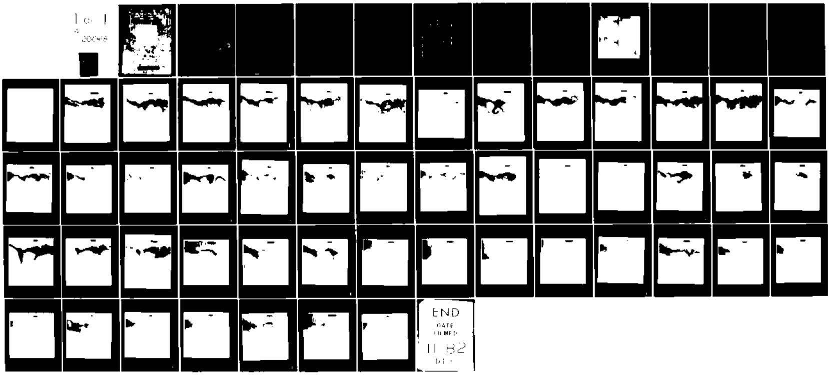

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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As part of the Coastal Ocean Dynamics Experiment infrared images from the weather satellite NOAA-6 were collected from late March to mid-July 1981. Images which met certain quality criteria were registered to a common grid and were screened to eliminate data which were cloud-contaminated. Infrared images yield approximate sea-surface temperature maps via the blackbody relationship. This report contains photographs of the digital images and a brief description of the processing techniques which were used.

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ABSTRACT

As part of the Coastal Ocean Dynamics Experiment infrared images from the weather satellite NOAA-6 were collected from late March to mid-July 1981. Images which met certain quality criteria were registered to a common grid and were screened to eliminate data which were cloud-contaminated. Infrared images yield approximate sea-surface temperature maps via the blackbody relationship. This report contains photographs of the digital images and a brief description of the processing techniques which were used.

INTRODUCTION

As part of the Coastal Ocean Dynamics Experiment (CODE) infrared images from an orbiting weather satellite were collected at the Scripps Satellite Oceanography Facility (SSOF). The site of the experiment is between Pt. Arena and Pt. Reyes on the northern California coast. The digital satellite images, which have a spatial resolution of approximately 1 km, cover a much larger area. Images were collected from the end of March 1981 until mid-July 1981. All the images which were collected were viewed, although not all of the images were processed because of the long computation time required for each image. All reasonably cloud-free images which coincided with experiments from research vessels were processed. Figure 1 shows the dates for which images were collected and viewed, and gives a coded description of the quality of each image. Both the year-day and the calendar dates are shown in Figure 1; the year-day is the convention used to catalogue satellite data at the SSOF. The quality of an image is determined primarily by the amount of sea surface which is not obscured by clouds. For those images which were fully processed and which appear in this report, a page number appears above the image-quality designation in Figure 1. A few images which were fully processed were not included in this report because they contained so little information near the CODE site.

The digital data were transmitted to the tracking antenna at the SSOF by the NOAA-6 satellite as it passed over the CODE site. The NOAA-6 satellite is a polar-orbiting, sun-synchronous satellite, which passes overhead twice per day, once from north-to-south (descending) and once from south-to-north (ascending). NOAA-6 passes over the CODE site

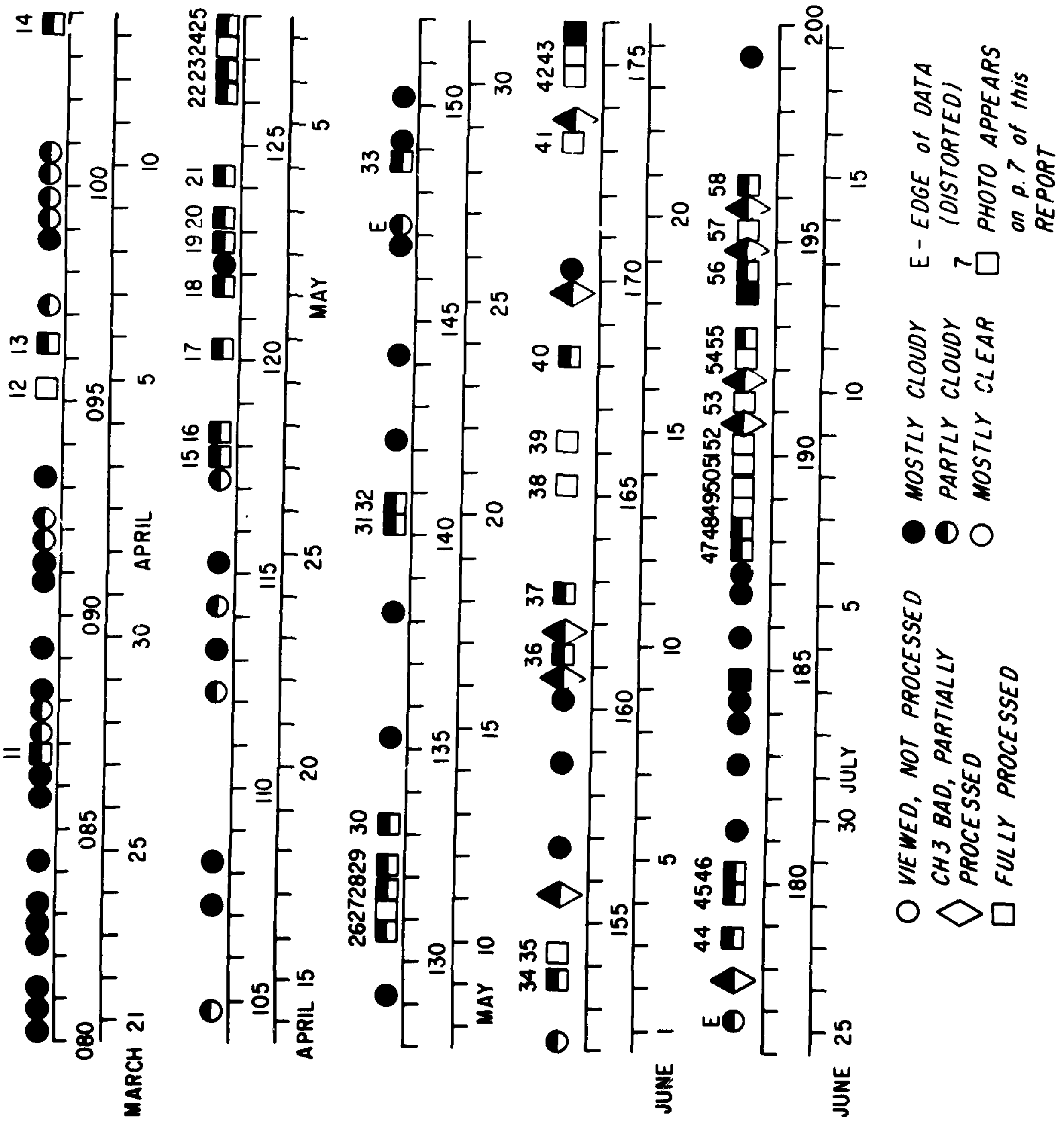

FIG. 1 - SATELLITE DATA AVAILABILITY FOR CODE - 1.

at approximately 0400Z (9 pm PDT) and 1600Z (9 am PDT). The satellite contains an advanced very high resolution radiometer (AVHRR) which scans simultaneously in four channels, two of which are in the infrared range at 3.7μm and 11μm. The infrared channels are used to derive sea-surface temperature information. Channels 1 and 2 contain visible light information and can be used only on the morning pass. Channel 3 (3.7μm) has obvious instrument noise which has increased since NOAA-6 was launched in the summer of 1979. The replacement for NOAA-6, NOAA-7, was launched during CODE-1, but was not operational until mid-July. Many morning images had a hazy channel 3 image, probably due to aerosol scatter or to reflected solar IR radiation. These images were registered, but could not be fully processed because the channel 3 image is needed for flagging cloud-contaminated areas. These images, many of which have large cloud-free areas, are not included in this report and are designated in Figure 1 by a diamond-shaped quality symbol.

The images selected for processing were corrected for viewing-angle distortion and were registered to a common grid using satellite ephemeris. The error in registration using the satellite orbit is about 5 km; a reduction in error to less than 2 km was obtained by examining landmarks and translating the registered image. The grid covers a square approximately 550 km on a side, entirely containing the CODE site. Images were subsectioned for this report so that the CODE site appears in the center of the image. Each image shown in this report covers a square area approximately 280 km on a side. Data recorded near the edge of the scanner's view are greatly distorted in both geometry and in radiance values and were therefore not processed. These data are designated in Figure 1 by an "E" above the quality symbol.

Images from both channels 3 and 4 were required for the complete processing of the data. Channel 4 contains an image similar to channel 3, but which is virtually noise-free. The noise in channel 3 was removed by filtering out the high-wavenumber components of the difference between channel 3 and channel 4. The noise-removal process is illustrated in Figure 2. Figure 2a shows the channel 3 image, Figure 2b shows channel 3 minus channel 4, and Figure 2c shows the channel 3 image with the noise removed.

Cloud-contaminated data were flagged so that thermal atmospheric features would not be confused with sea-surface features. Although clouds tend to be colder than the sea surface, a threshold method to detect clouds is generally unreliable, especially in an area of active upwelling. The failure of a threshold method for cloud-detection was discussed by Coakley and Bretherton (1982). Clouds are more easily detectable in the difference of channel 3 and channel 4; however, even on the difference image the threshold method proved unreliable, in large part because of the contribution of channel 3 instrument noise. A series of algorithms was developed to flag the clouds which combines threshold techniques with pattern-recognition, in a method similar to that of Coakley and Bretherton. Figure 2d shows the images with the flagged areas masked by a constant value. Areas of the image containing land were also masked.

The infrared radiance values were converted to brightness temperatures (the equivalent blackbody temperature for the given radiance), using calibration data from the spacecraft. The AVHRR has a noise-equivalent temperature (NET), or precision, of 0.1 C., excluding the

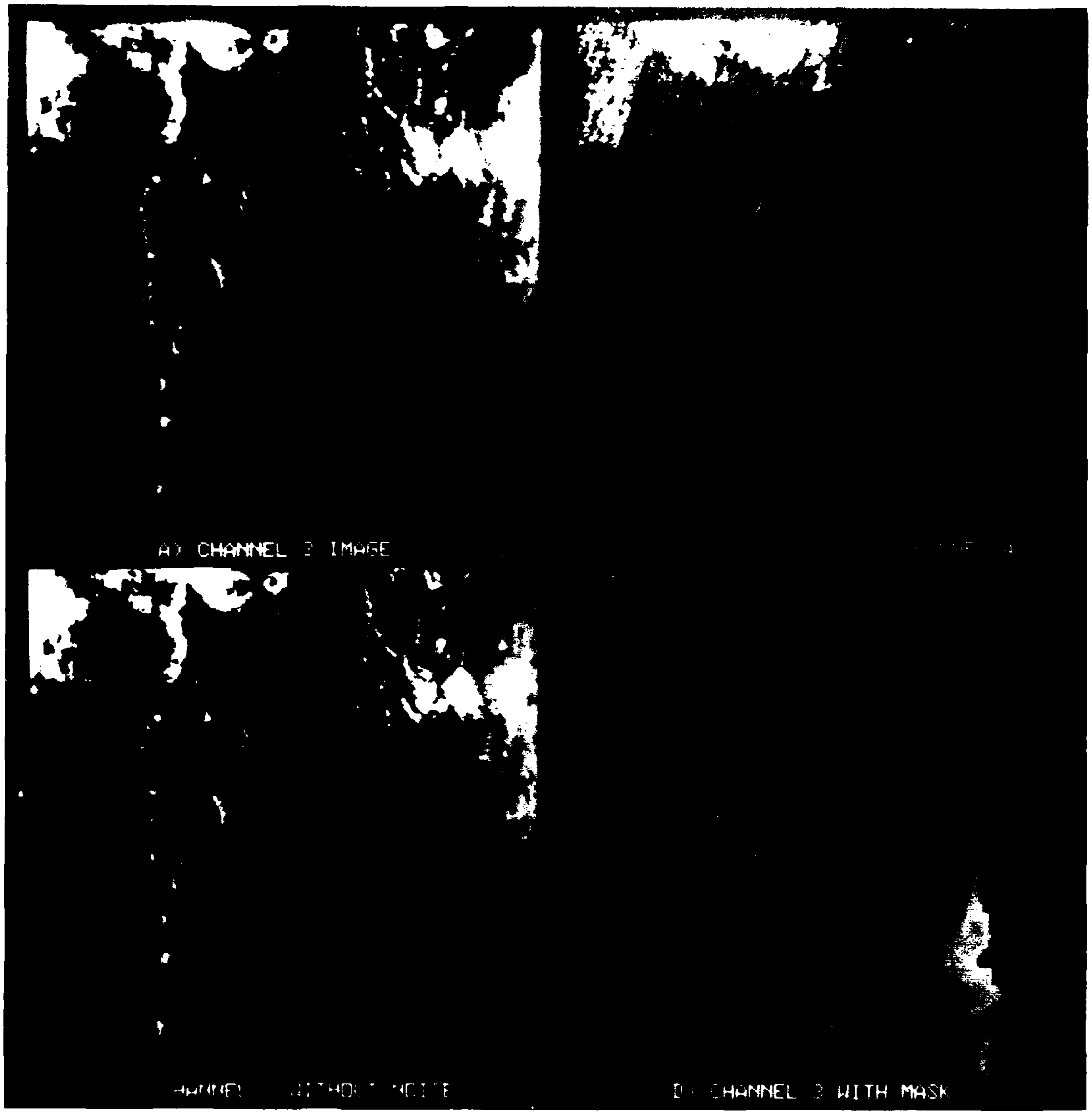

FIGURE 2. NOAA-6 INFRARED IMAGE AT SUCCESSIVE STEPS IN PROCESSING.

periodic instrument noise. The brightness temperatures are not, however, an accurate measure of the sea-surface temperature. These temperature values are generally 1-2 C. colder than near-surface measurements made with CTD's. A one-parameter correction for the effects of the atmosphere on temperature measurements which was developed by R. L. Bernstein uses the difference between channel 3 and channel 4 temperatures to correct the channel 3 values (1982). This concept was tested and determined to be ineffective on these images. Uncorrected images separated by 12 or 24 hours have rms temperature differences of 1 C. For comparison the one-hour average temperatures from the near-surface thermistors corresponding to the images had rms differences of 0.4 C. These differences can best be described as constants over the images and are not well-correlated with the difference between channel 3 and channel 4. The temperatures shown in this report are the uncorrected channel 3 values. In order to represent the sea-surface temperature data in a consistent way, despite the fluctuations in absolute temperature, each image was mapped over a 7 C. range. The range was chosen to display most of the features, with an emphasis on the cold features near the coast. For example, the image shown on page 38 was mapped from 6 to 13 C. All values less than 6 C. were mapped to 6 and all values greater than 13 C. were mapped to 13. All values between 6 and 13 were mapped linearly to the 256 gray shades available on the digital display. The next image was mapped from 7 to 14 C. The first several images (until early May) had so little temperature contrast that they were enhanced over a smaller temperature range so that features are visible. The temperature scale on each image can be used to determine relative temperatures. The temperature scale indicates the gray tones associated with whole degrees C.; however, there are many gray shades in between those shown on the scale.

The pictures in this report were made by photographing the image on a digital display at the SSOF. Each image corresponds to an array of temperature data which has a row dimension of 256 and a column dimension of 256; thus each image contains 65,536 temperature values. The images were expanded by a factor of 2 in each direction to fill a 512 X 512 element display. Each element in an array which is displayed as an image is called a pixel; thus each image here contains 262,144 pixels. A significant loss in temperature resolution occurs when the display is photographed because film cannot resolve 256 gray shades.

Superimposed on each image is a longitude-latitude grid at one degree intervals, an outline of the coast, a temperature scale and a label identifying the date and time the image was scanned. For example, the image labeled C81.095.04 was scanned on the 95th day of 1981 at approximately 0400Z. For convenience the calendar date and local time are given on the next line. An image of the size shown in this report is scanned in approximately one minute. Bathymetry for the CODE site is shown on the same grid as the images on page 11.

The satellite data will be analyzed for dominant modes using empirical orthogonal functions. These modes will be compared with other variables such as winds and bathymetry to investigate the source of the sea-surface temperature patterns. In addition the images will be compared with surface velocity measurements from CODE to determine if a simple and consistent method for estimating velocities from consecutive images can be found.

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Coakley, J.F. and F. P. Bretherton, Cloud Cover from High Resolution Scanner Data: Detecting and Allowing for Partially Filled Fields of View, J. Geophys. Res., 87, 4917-4932, 1982.

Bernstein, R. L. (1982) personal communication.

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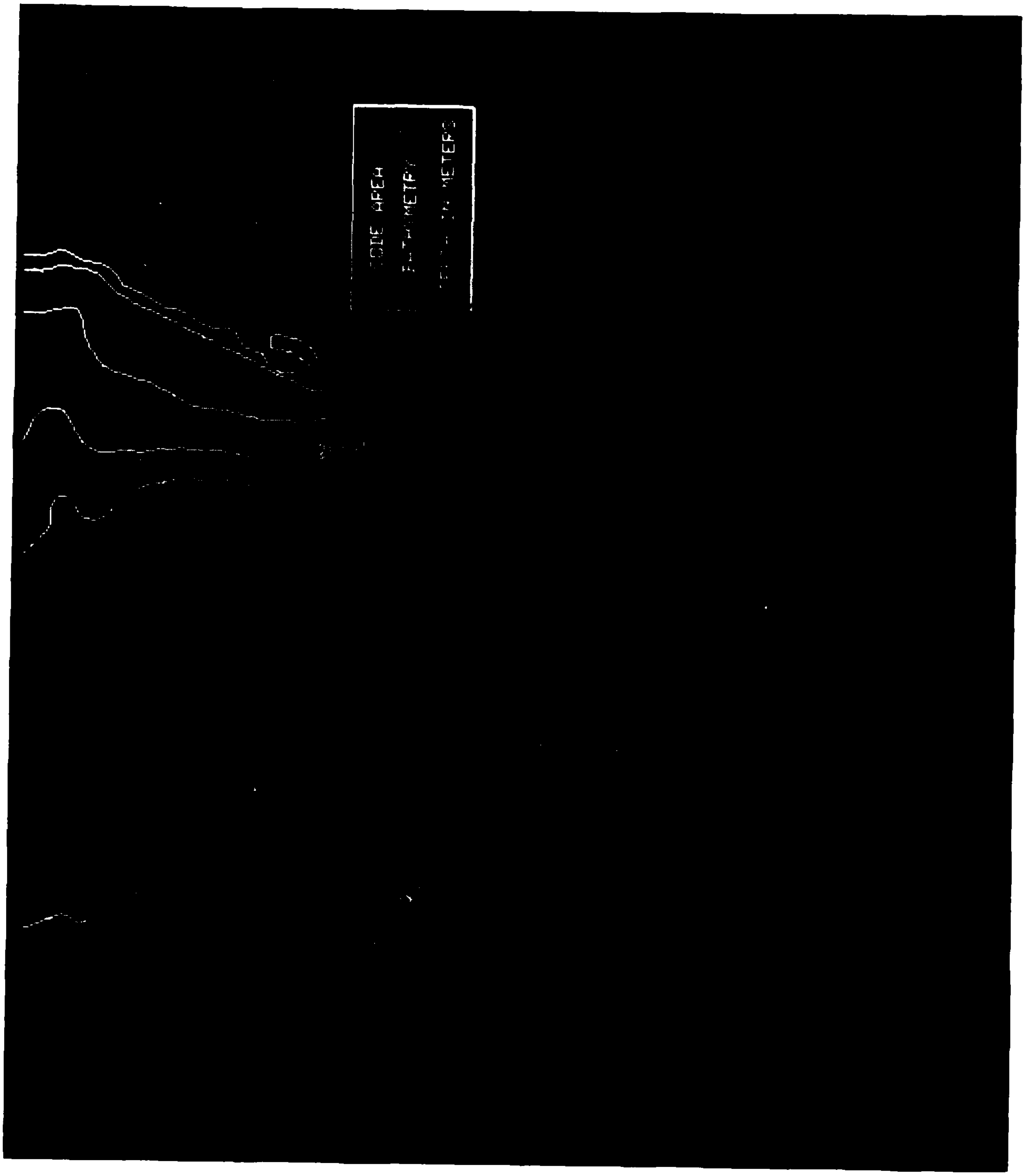
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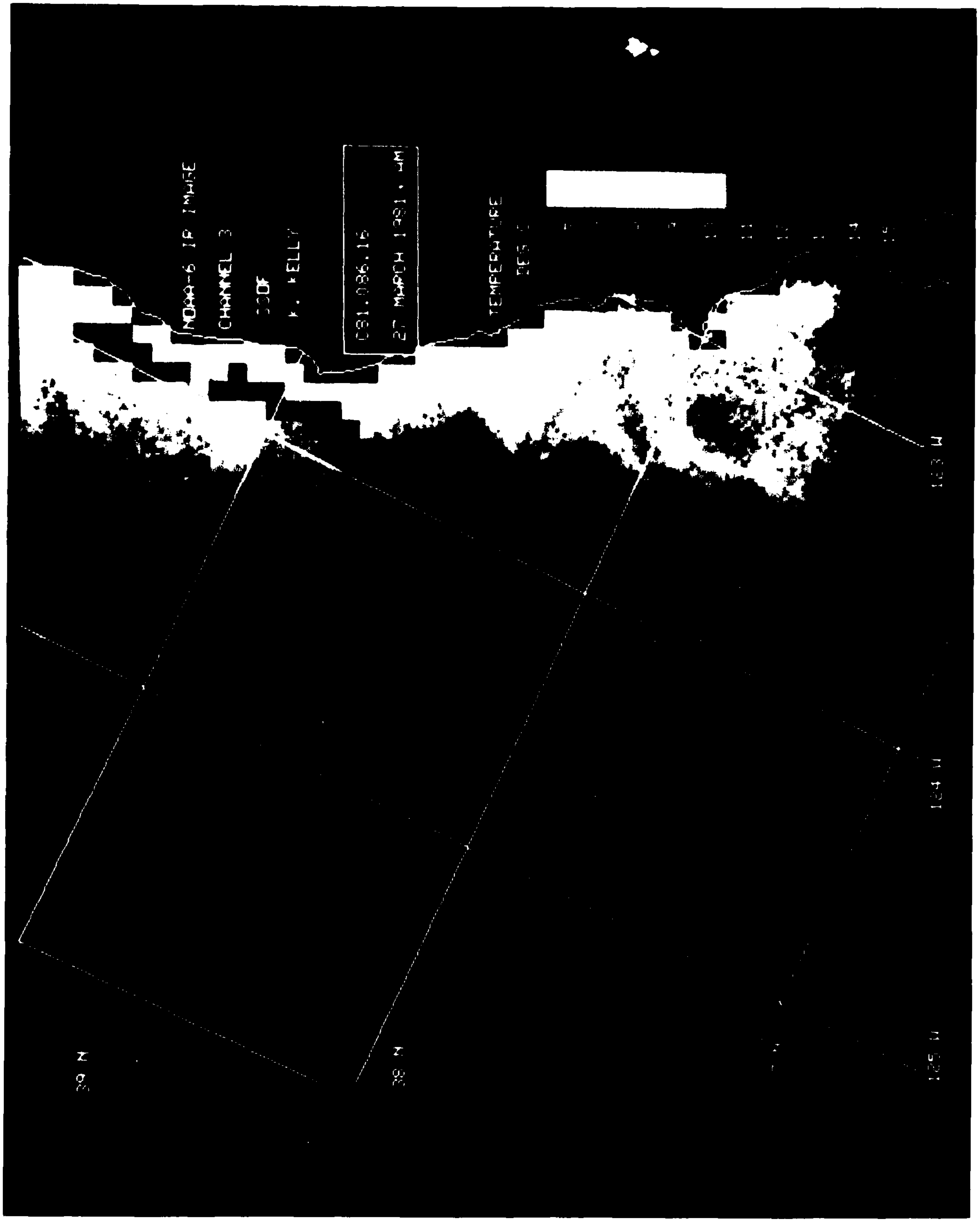
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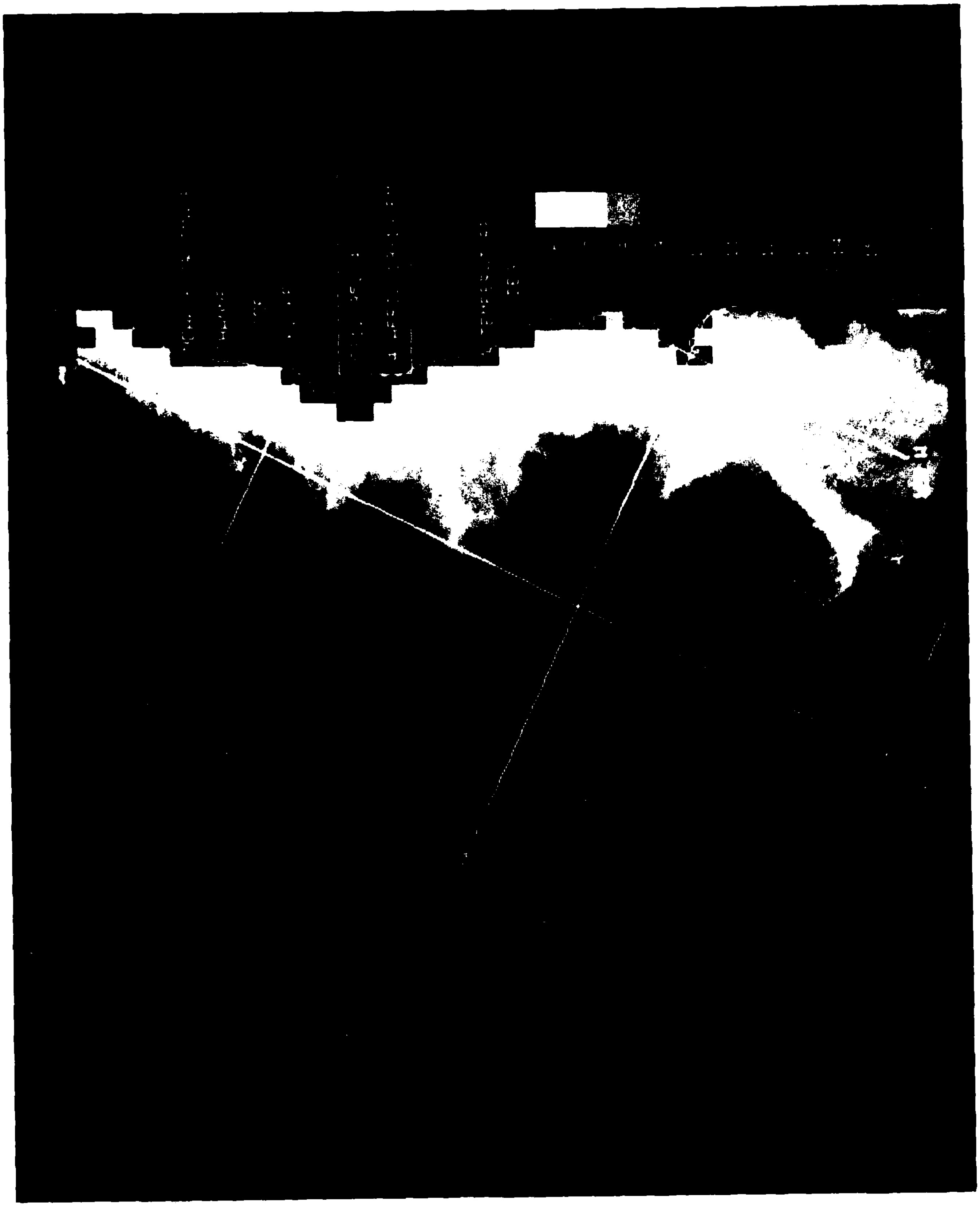

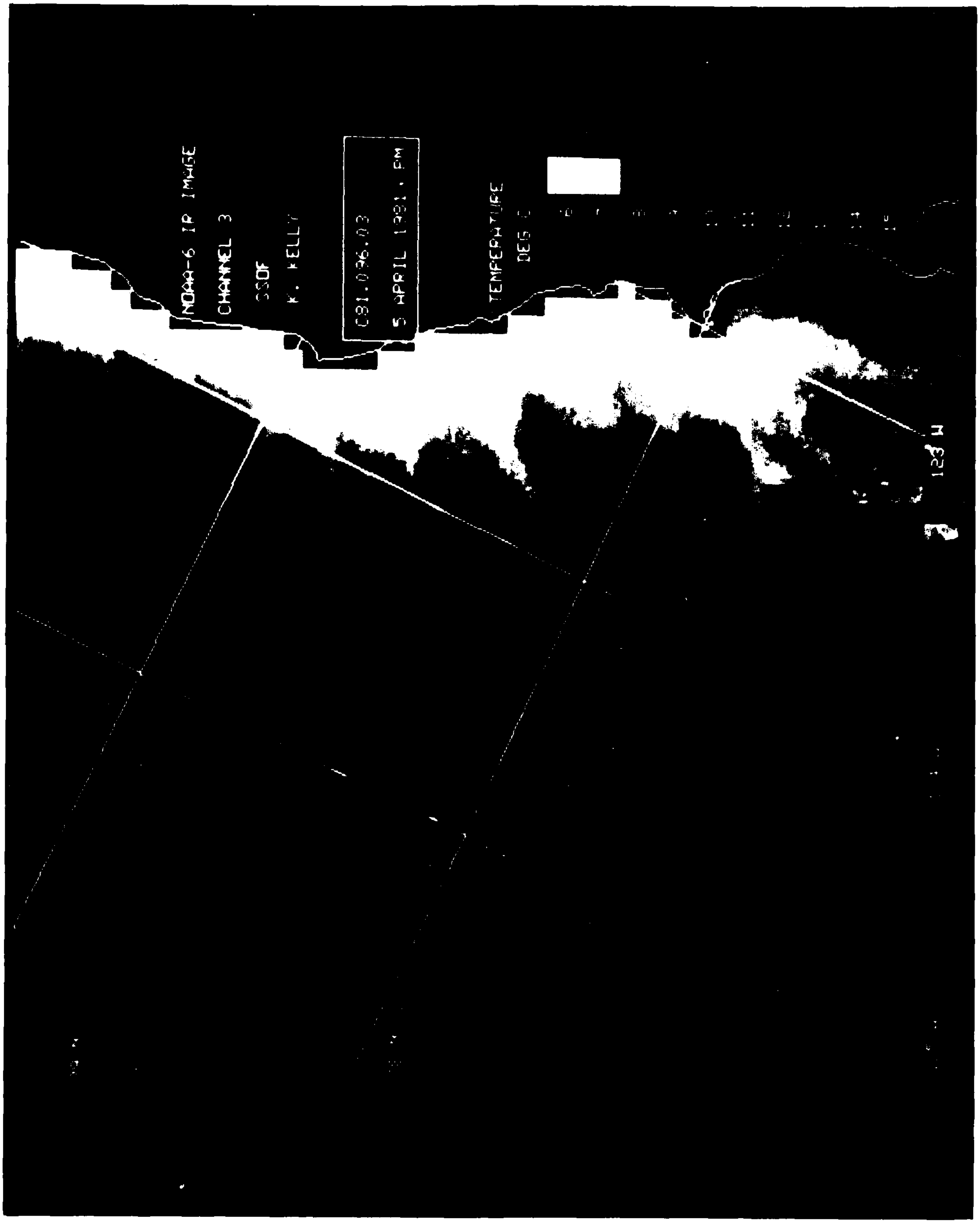
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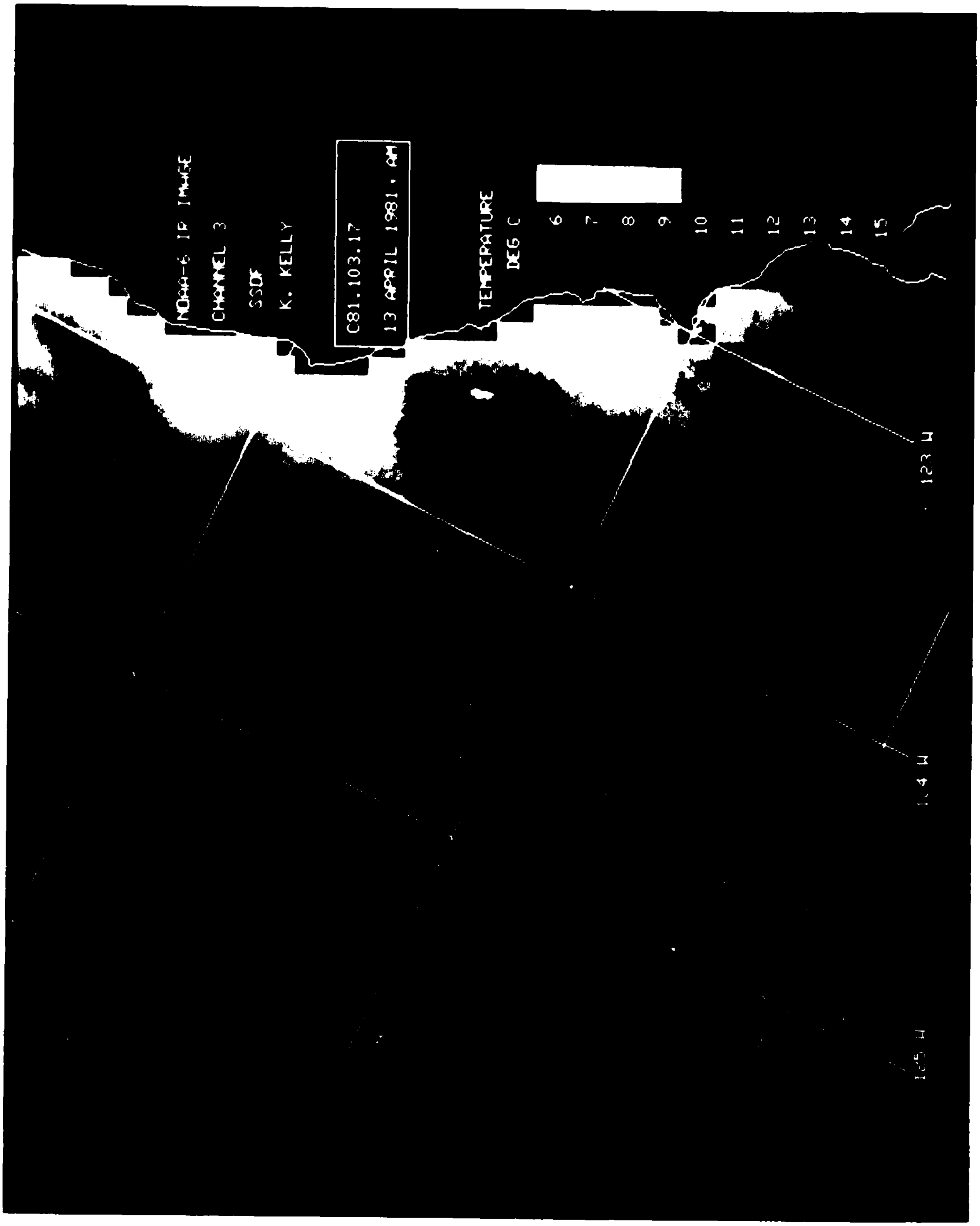
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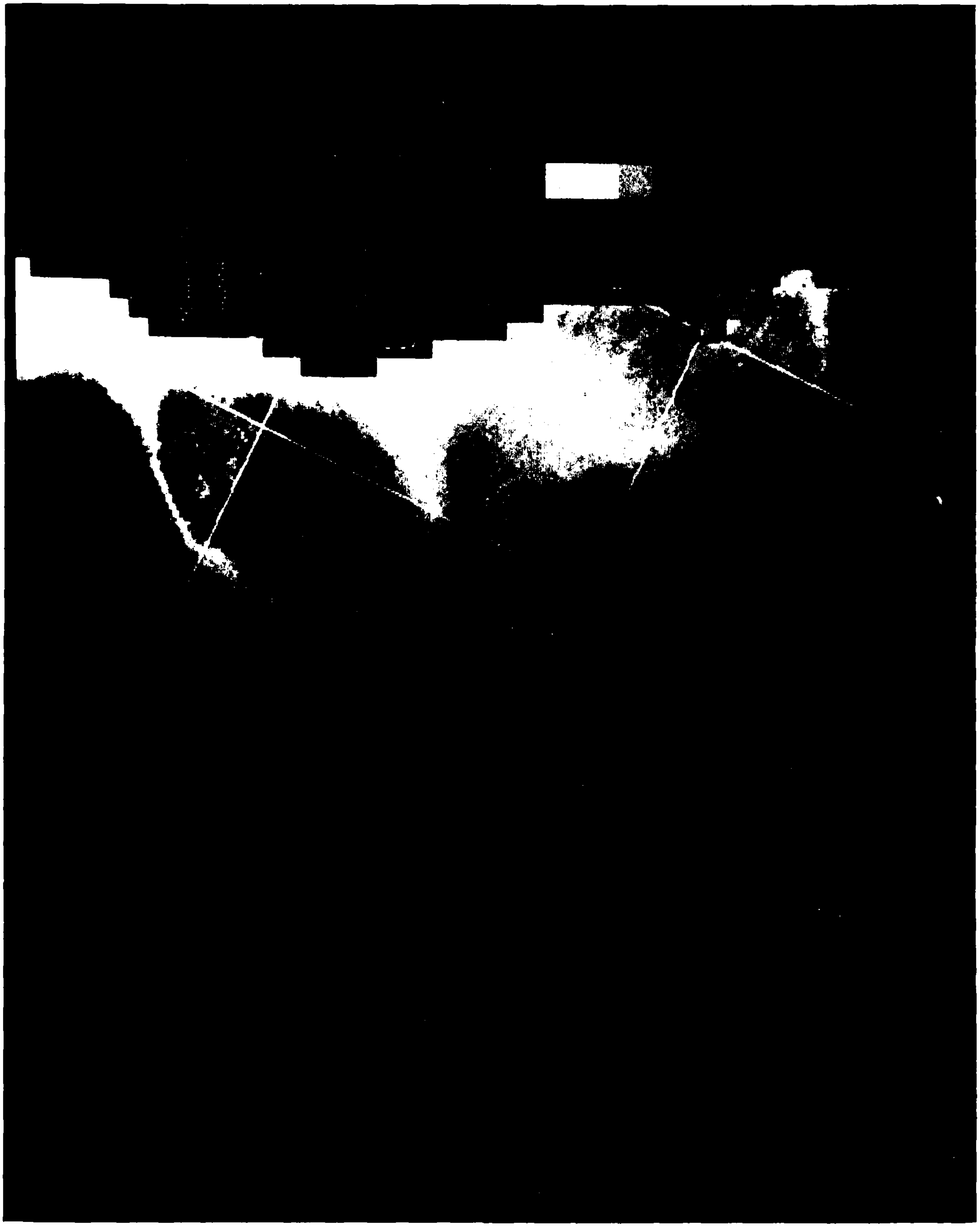

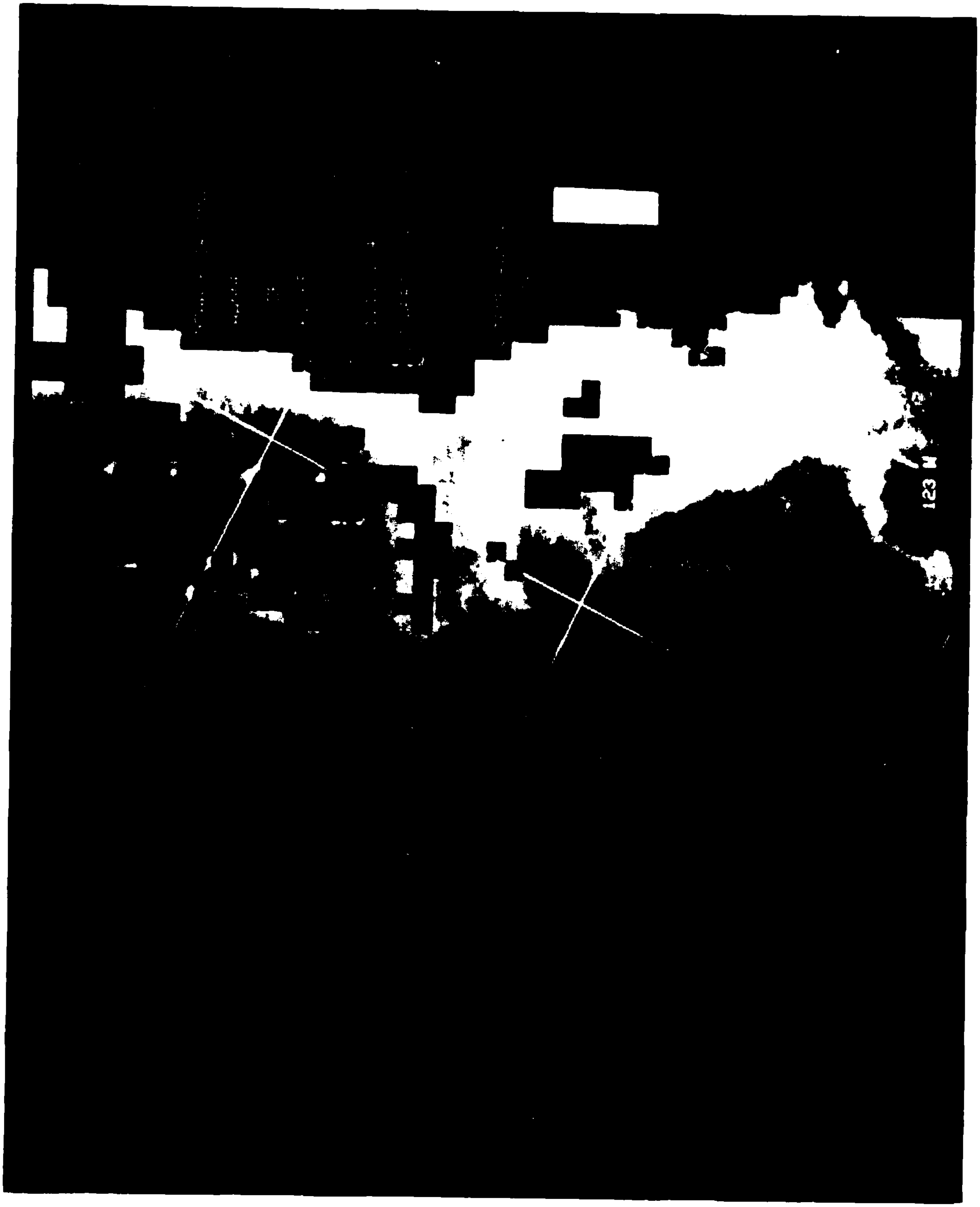
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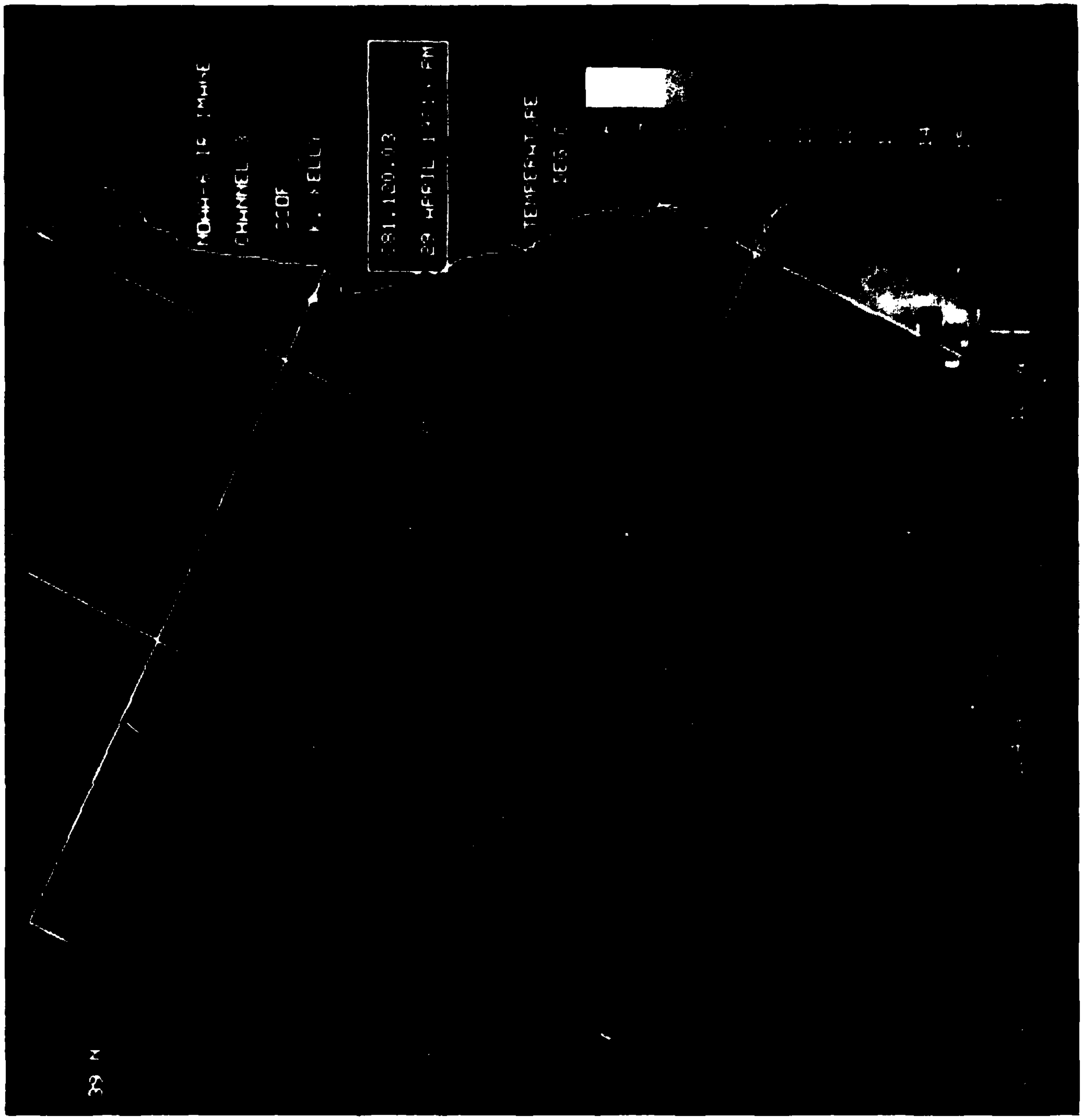

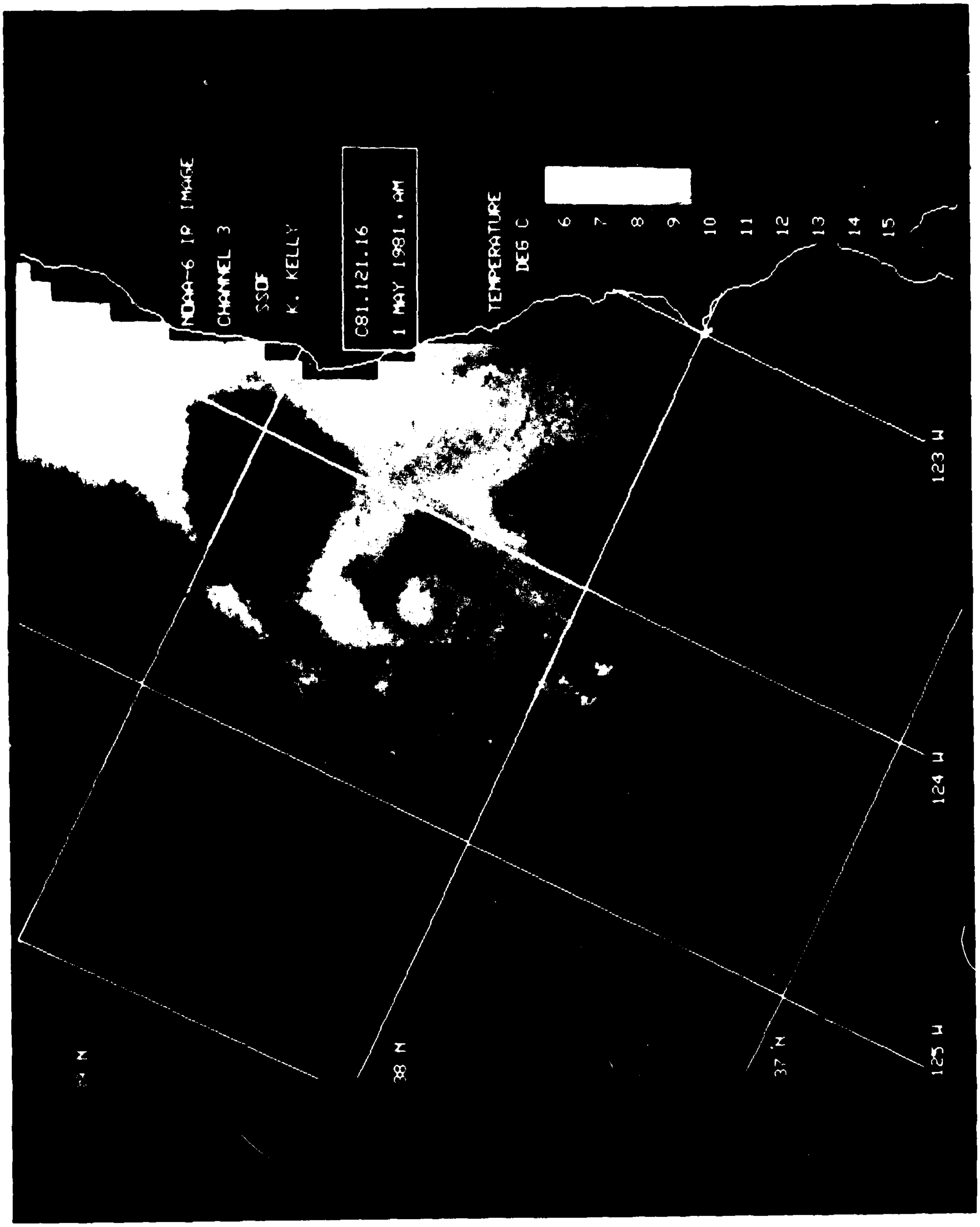
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K. KELLY
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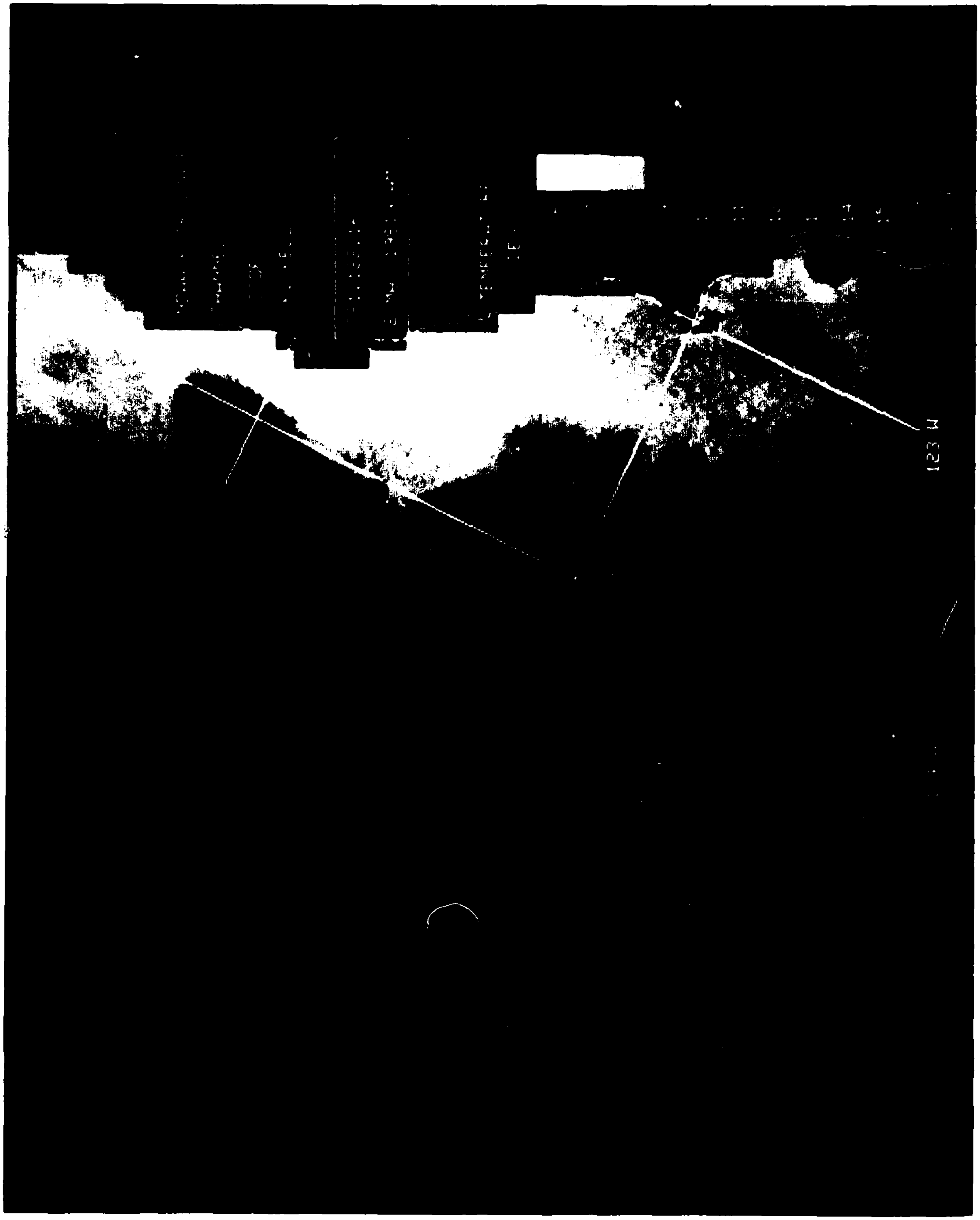
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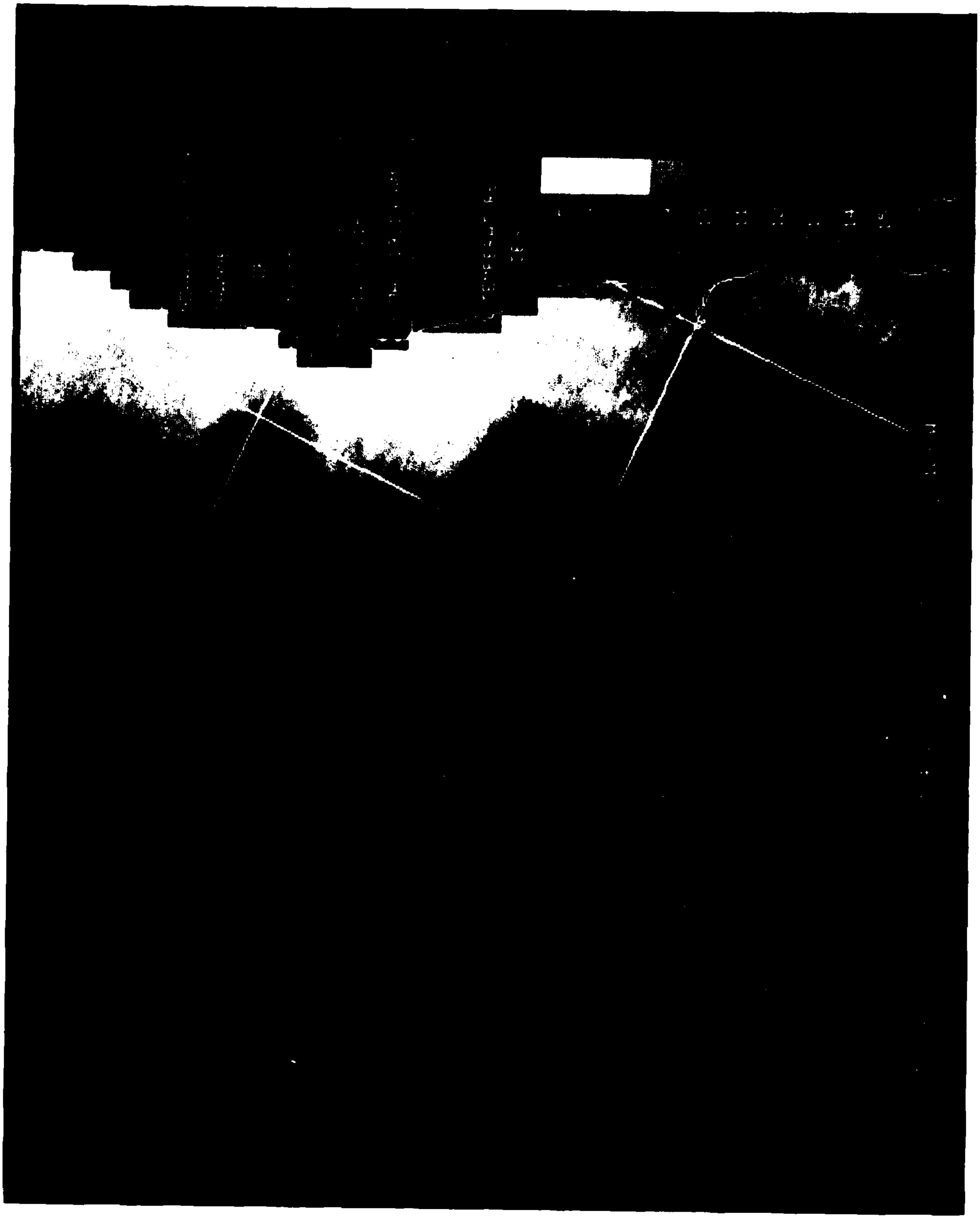

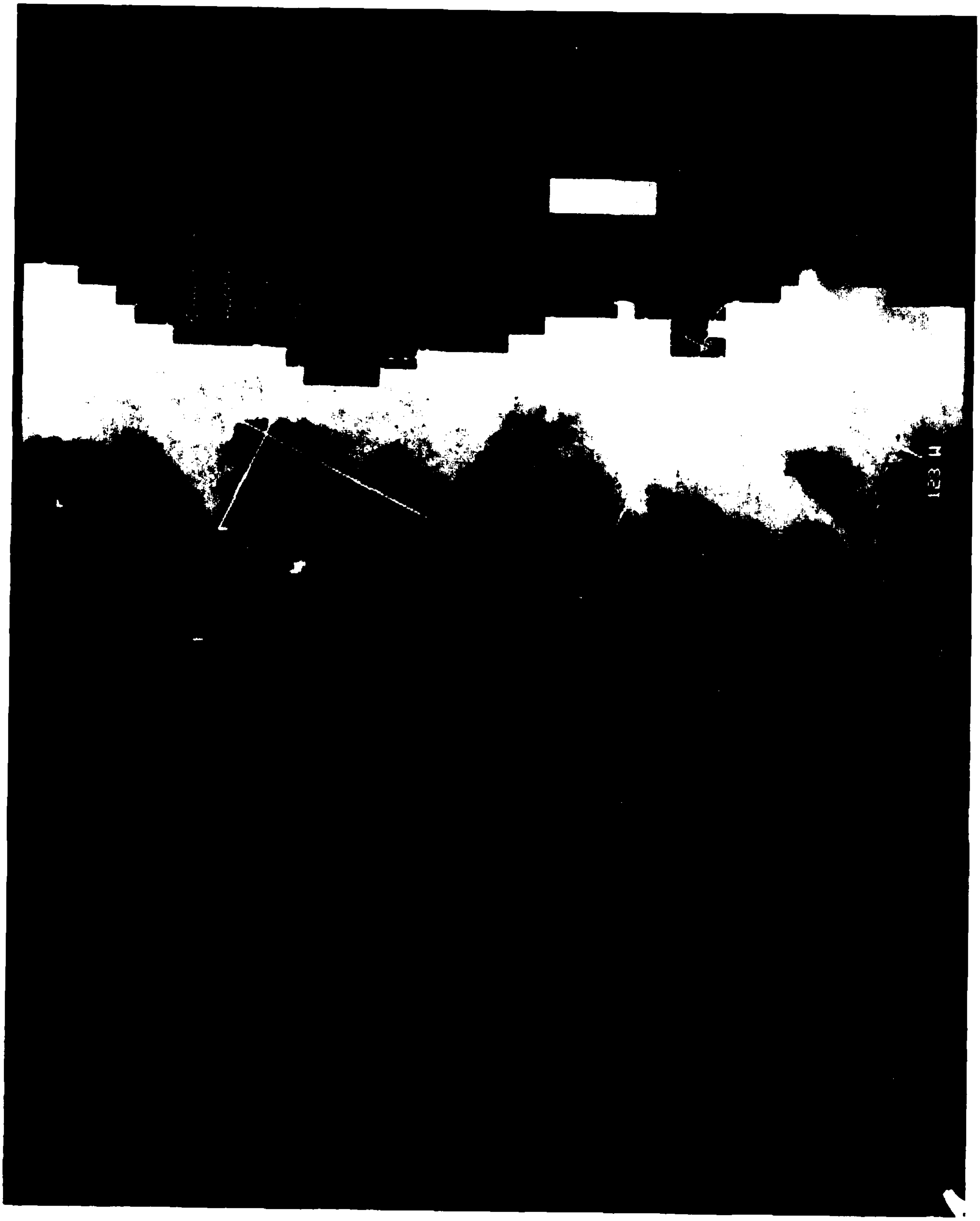
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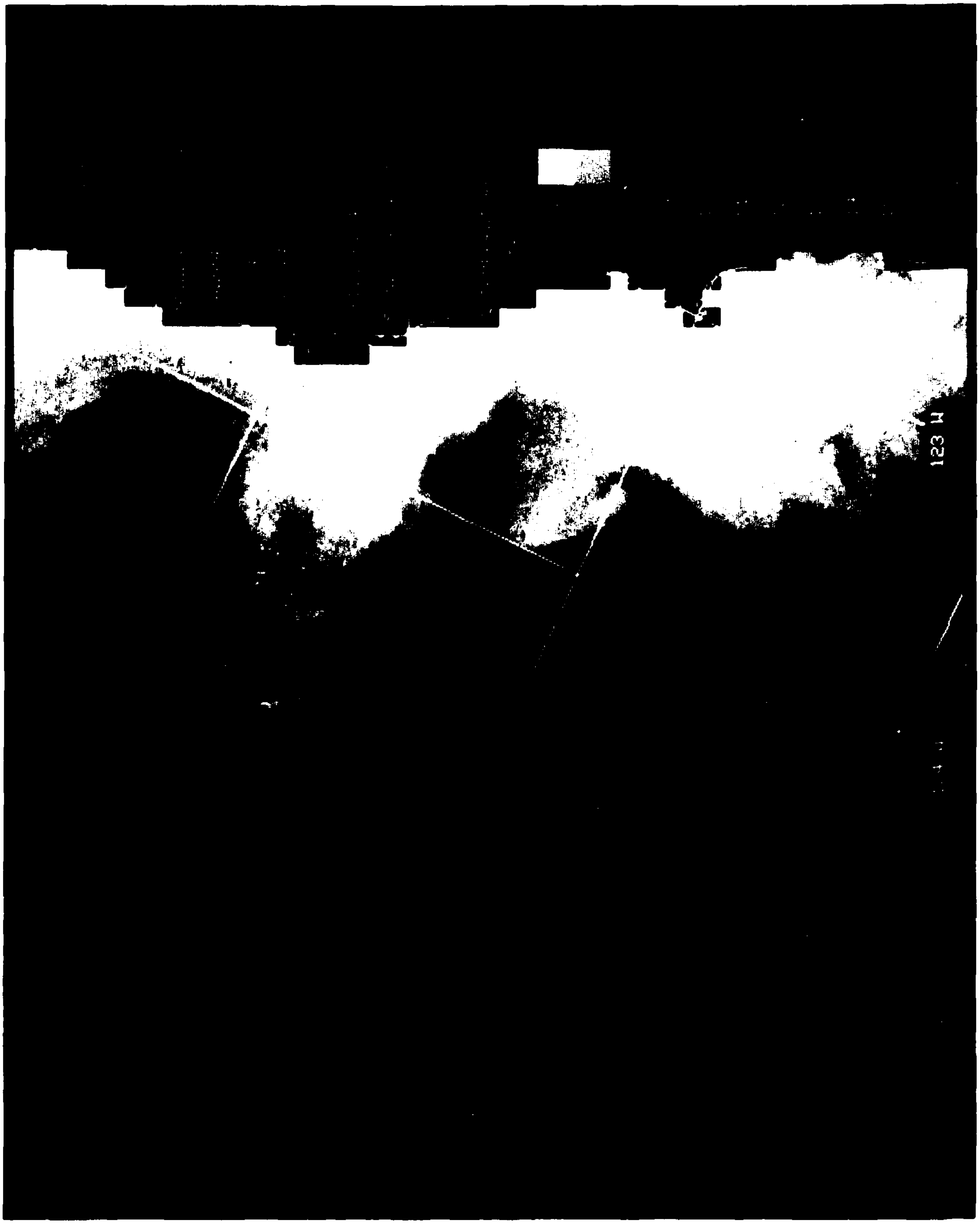
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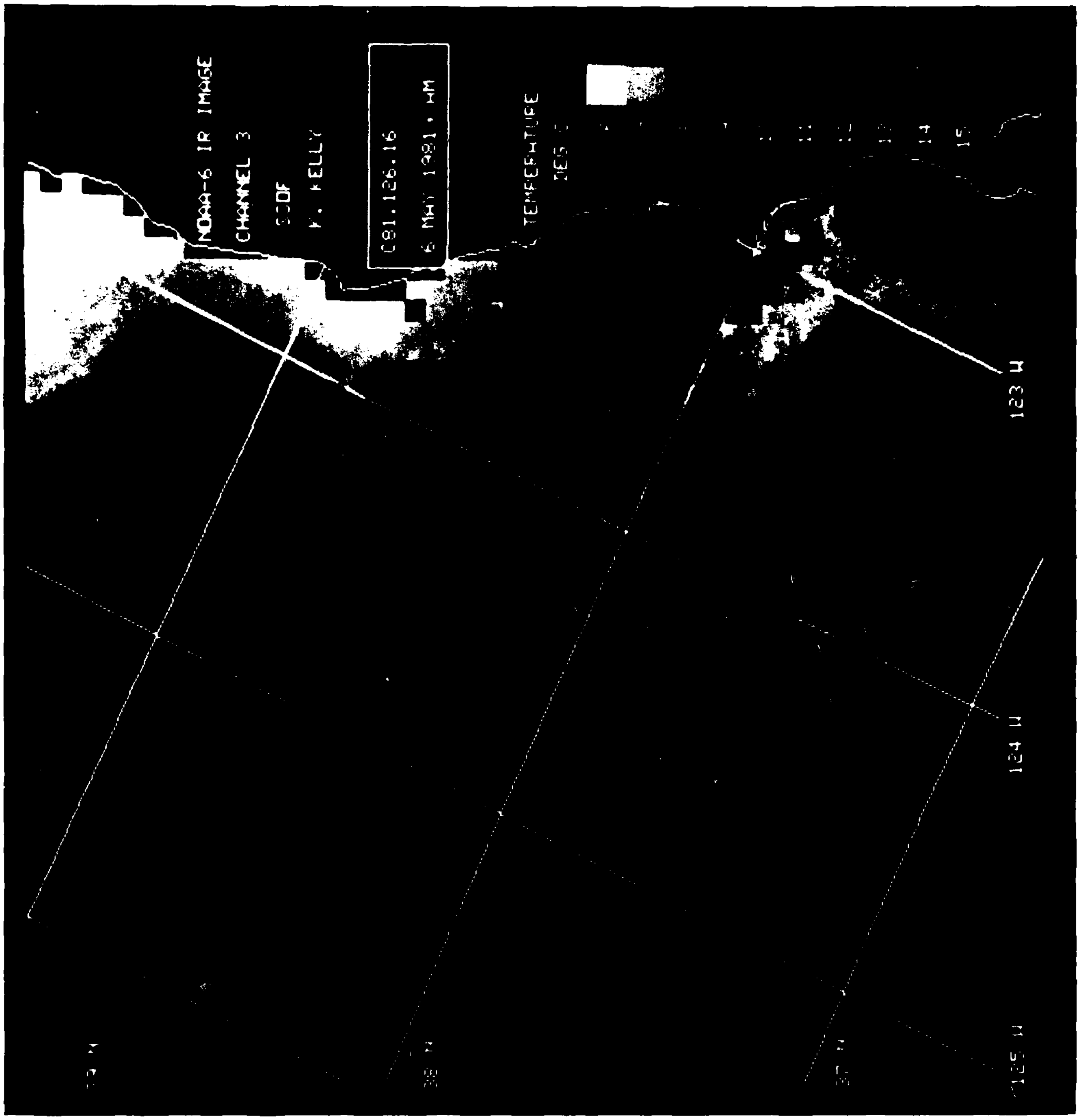
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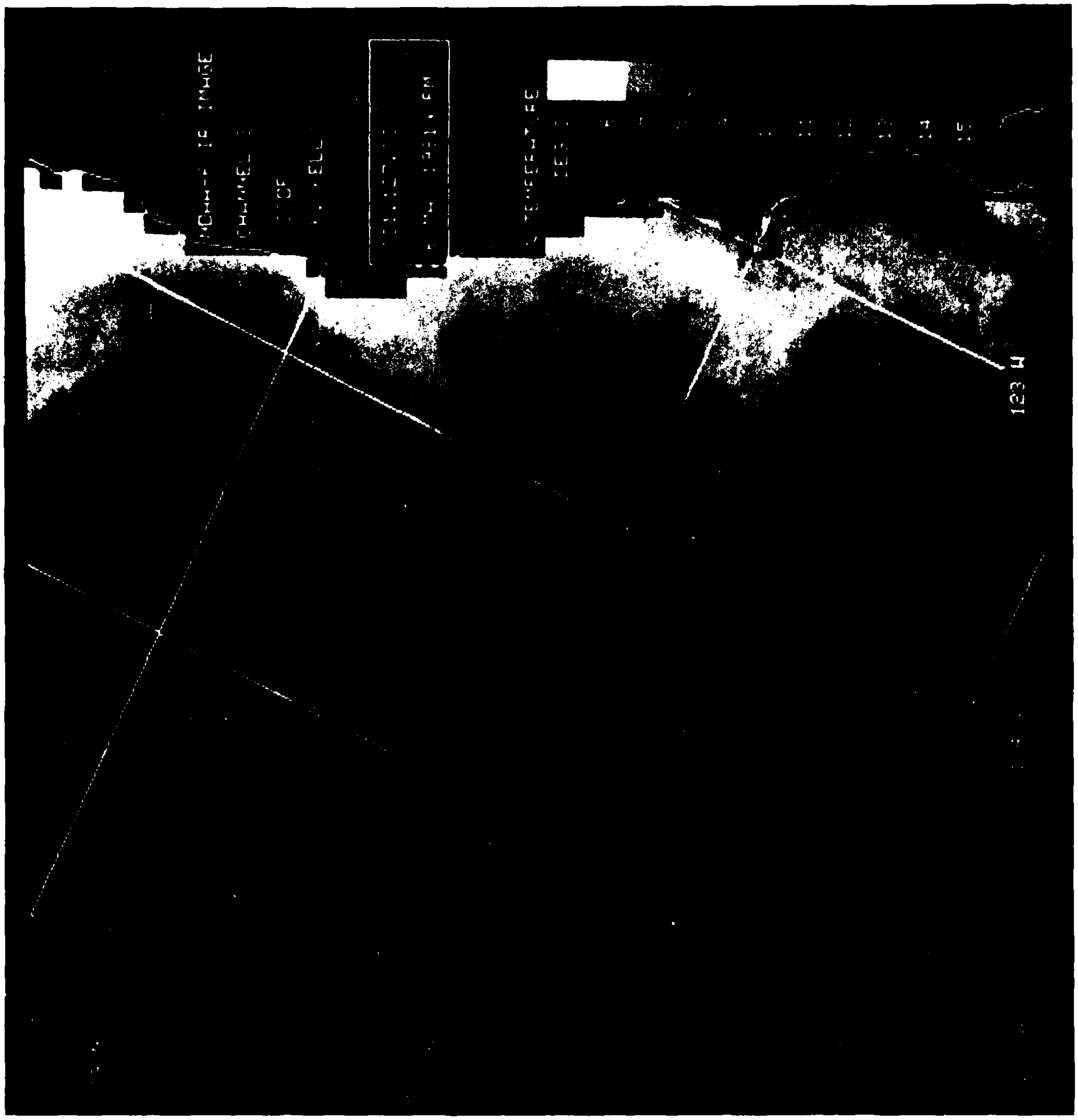

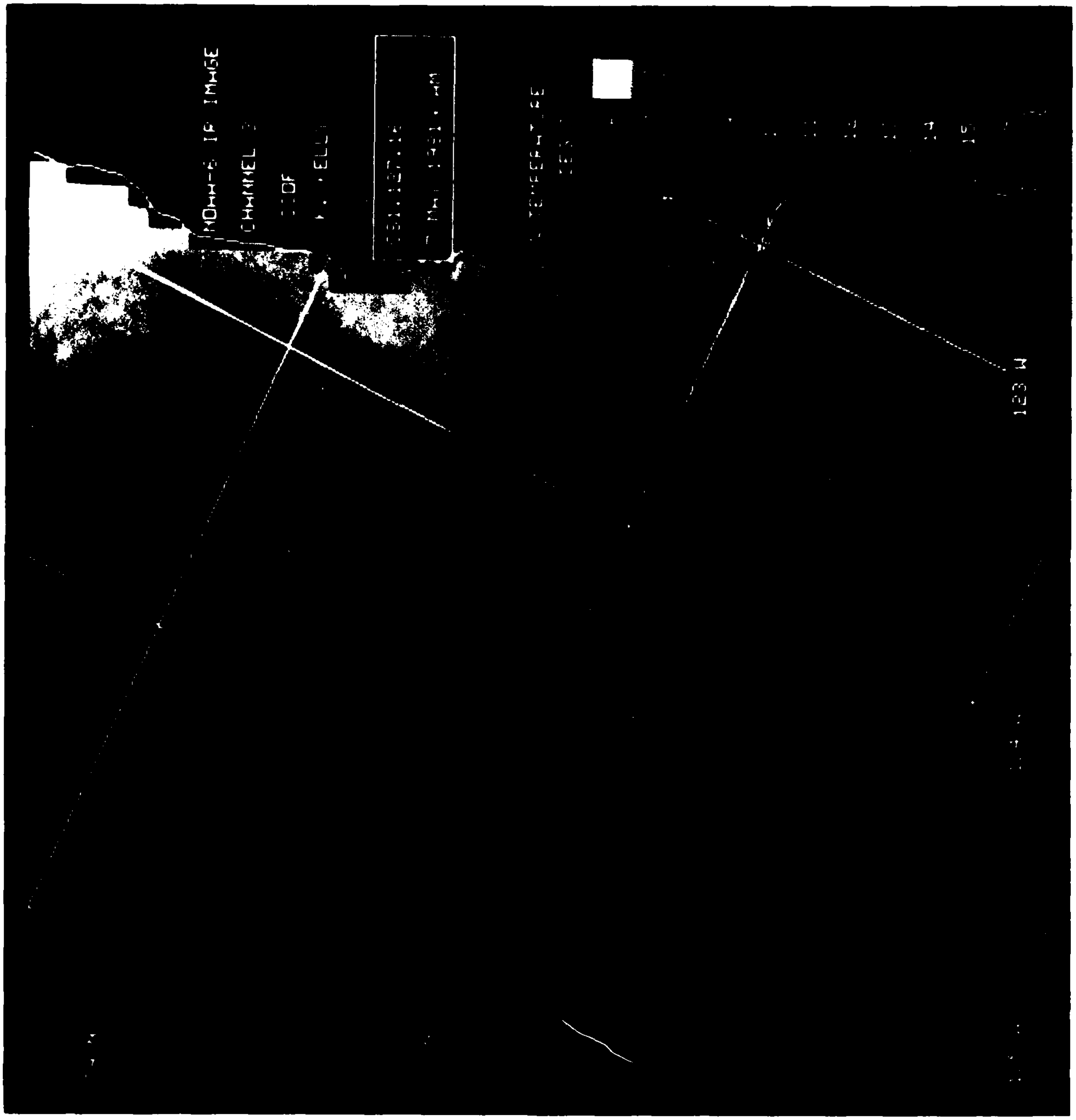
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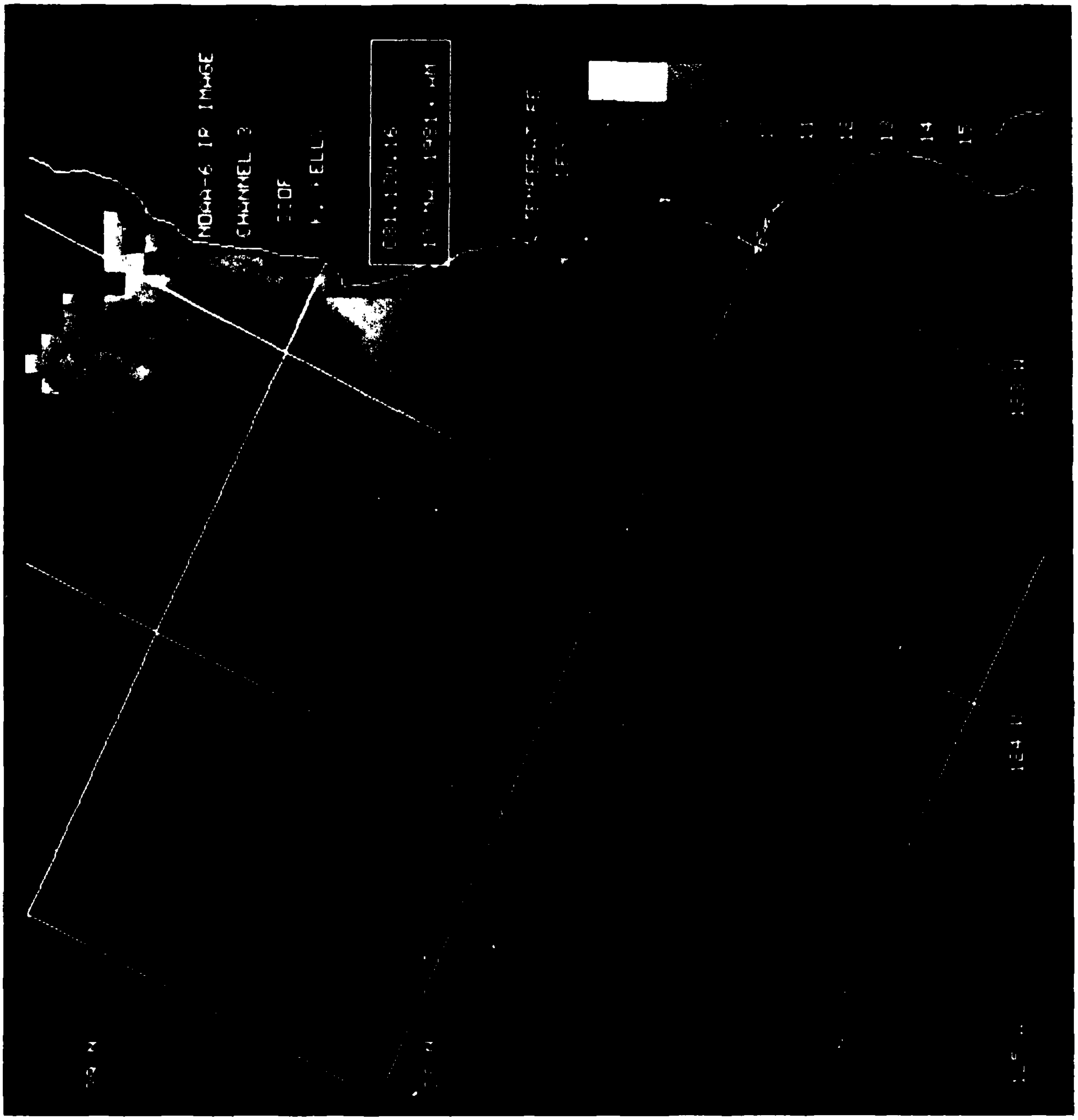
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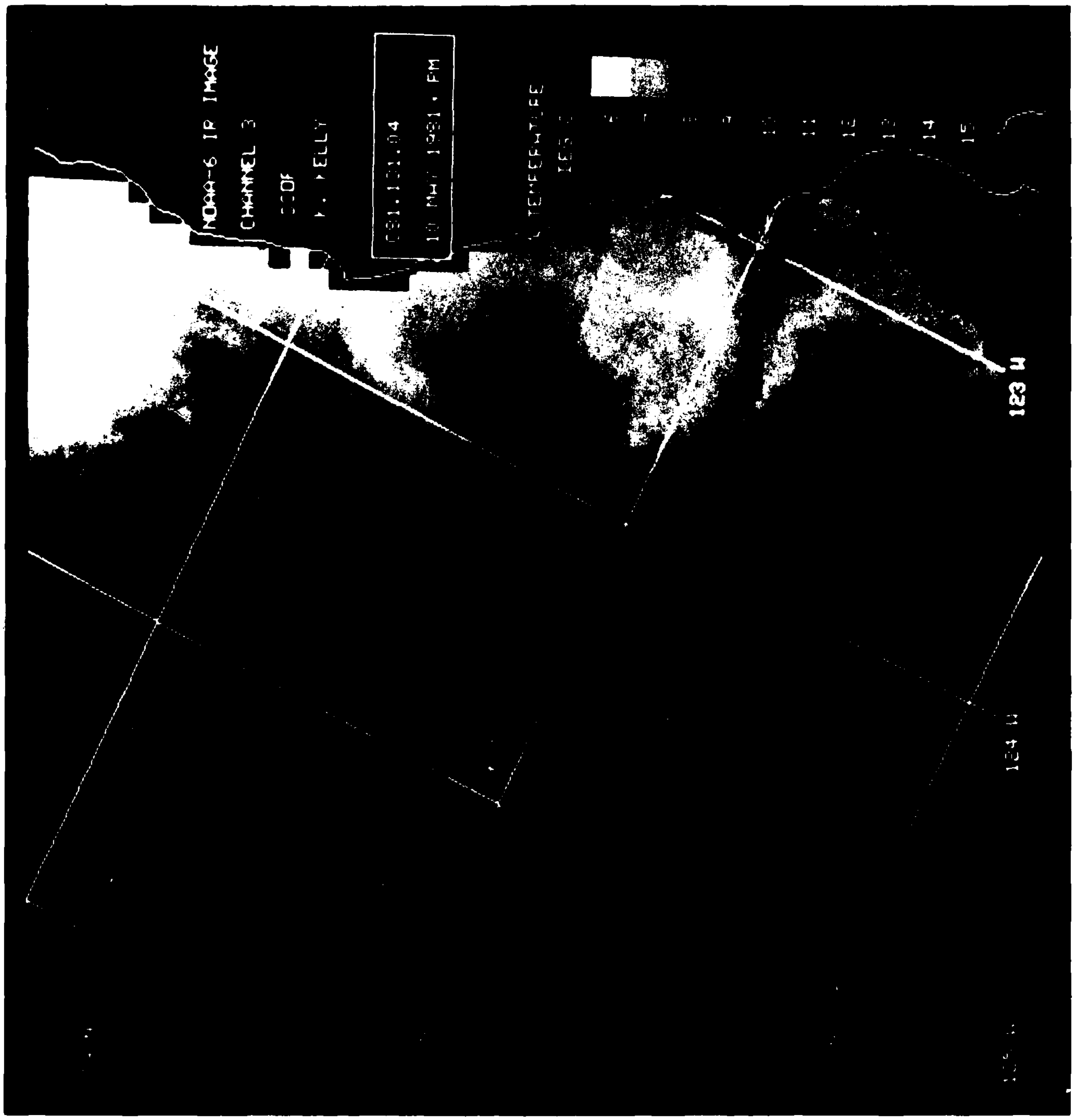
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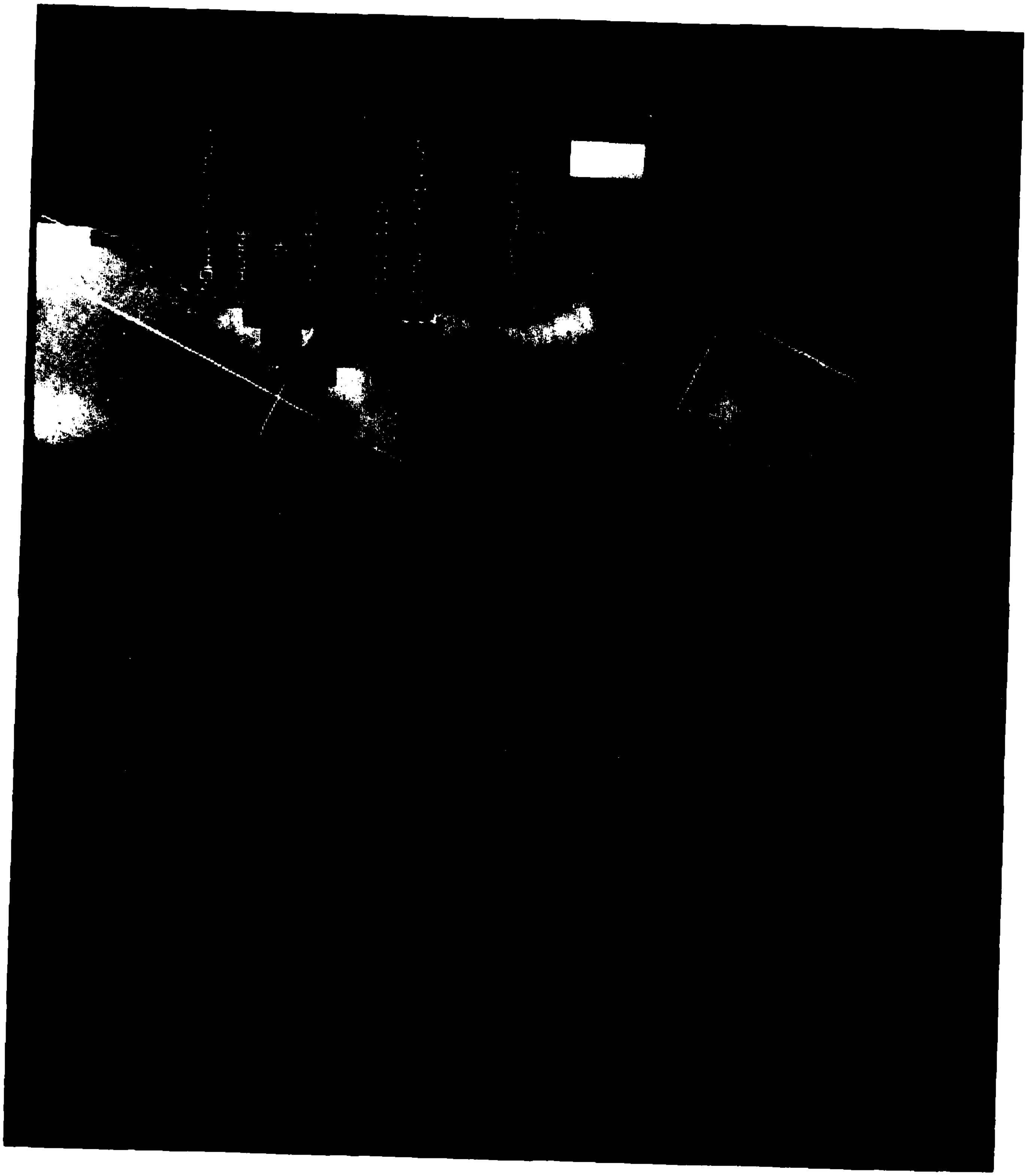

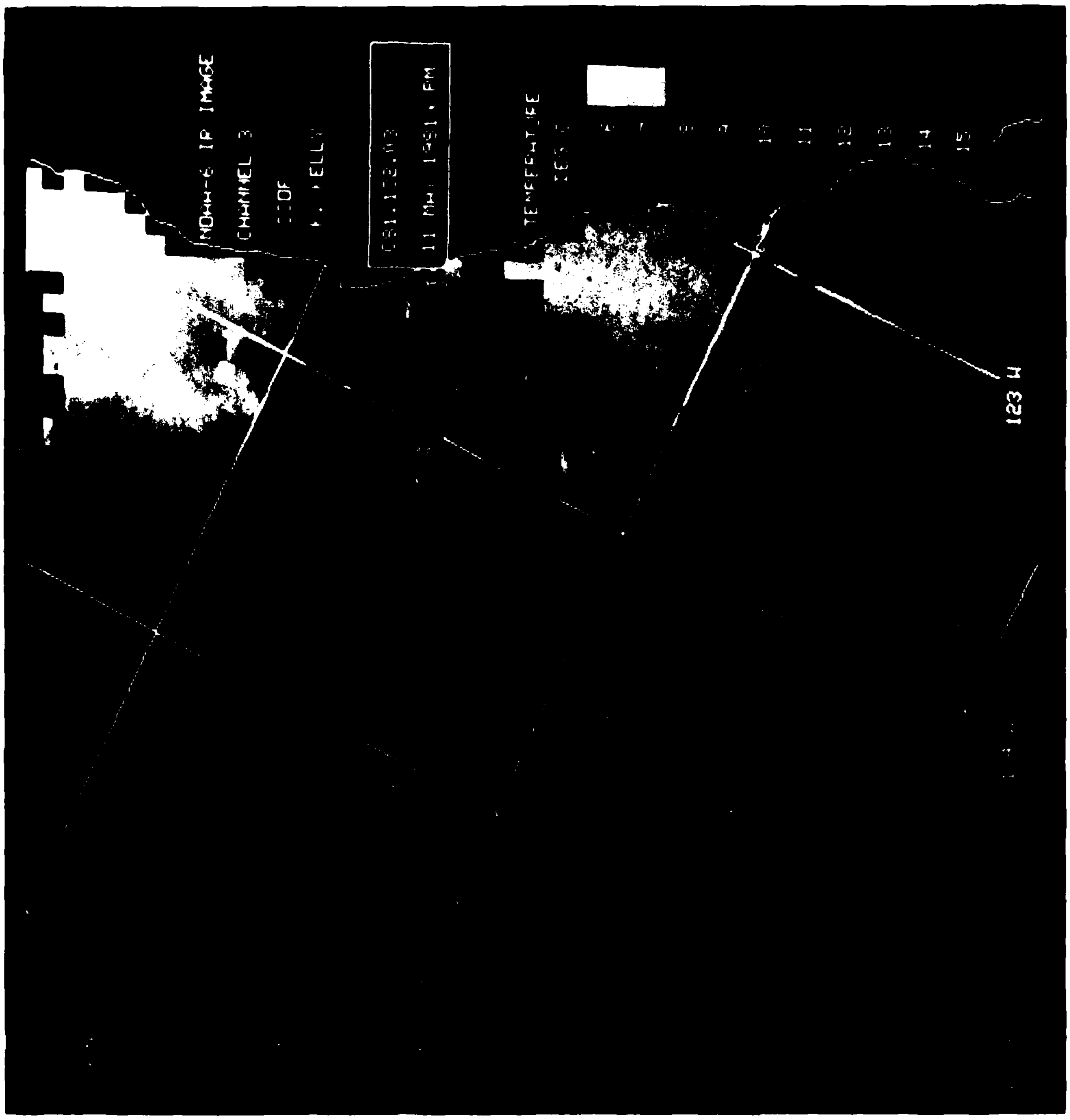
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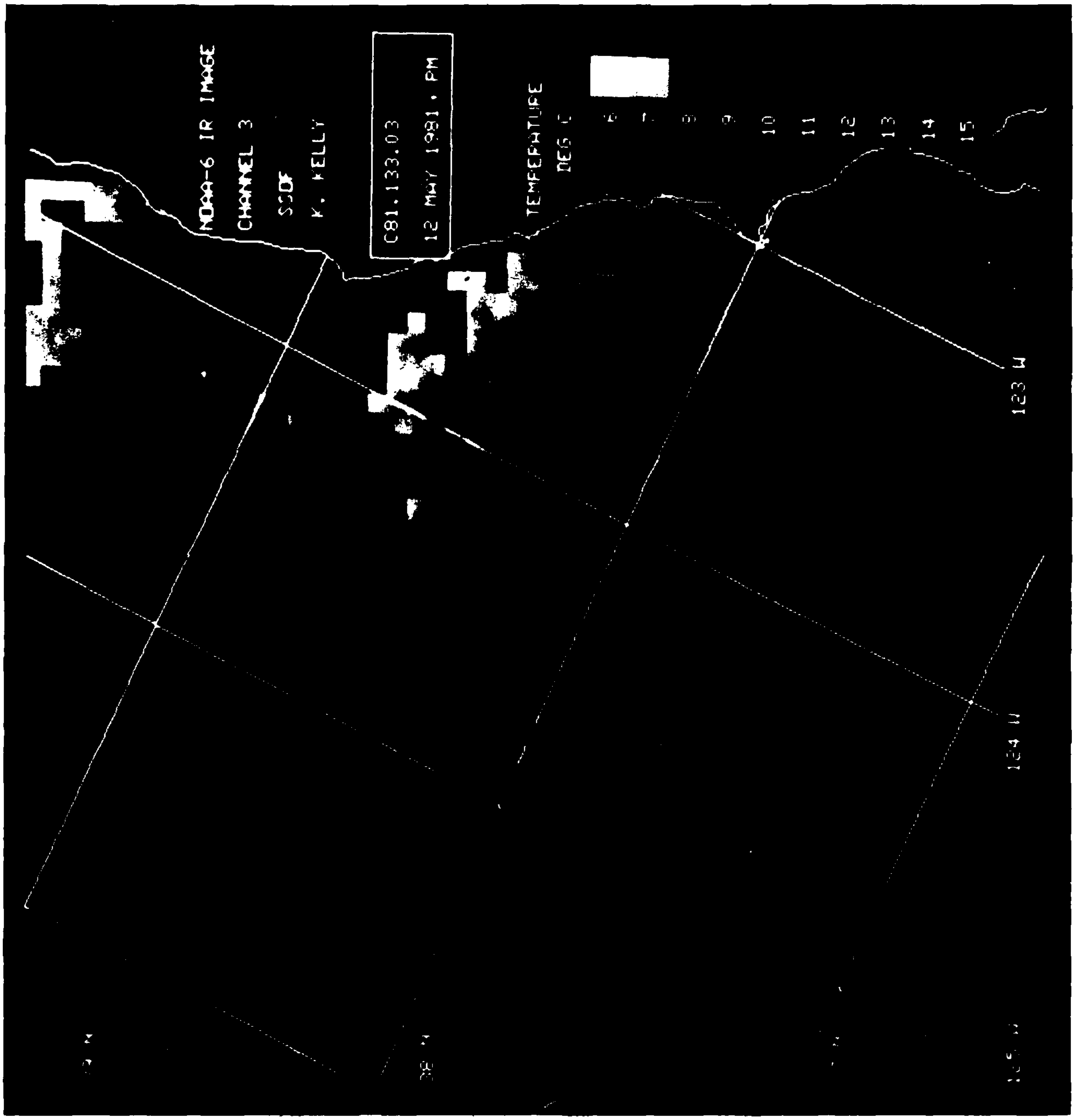
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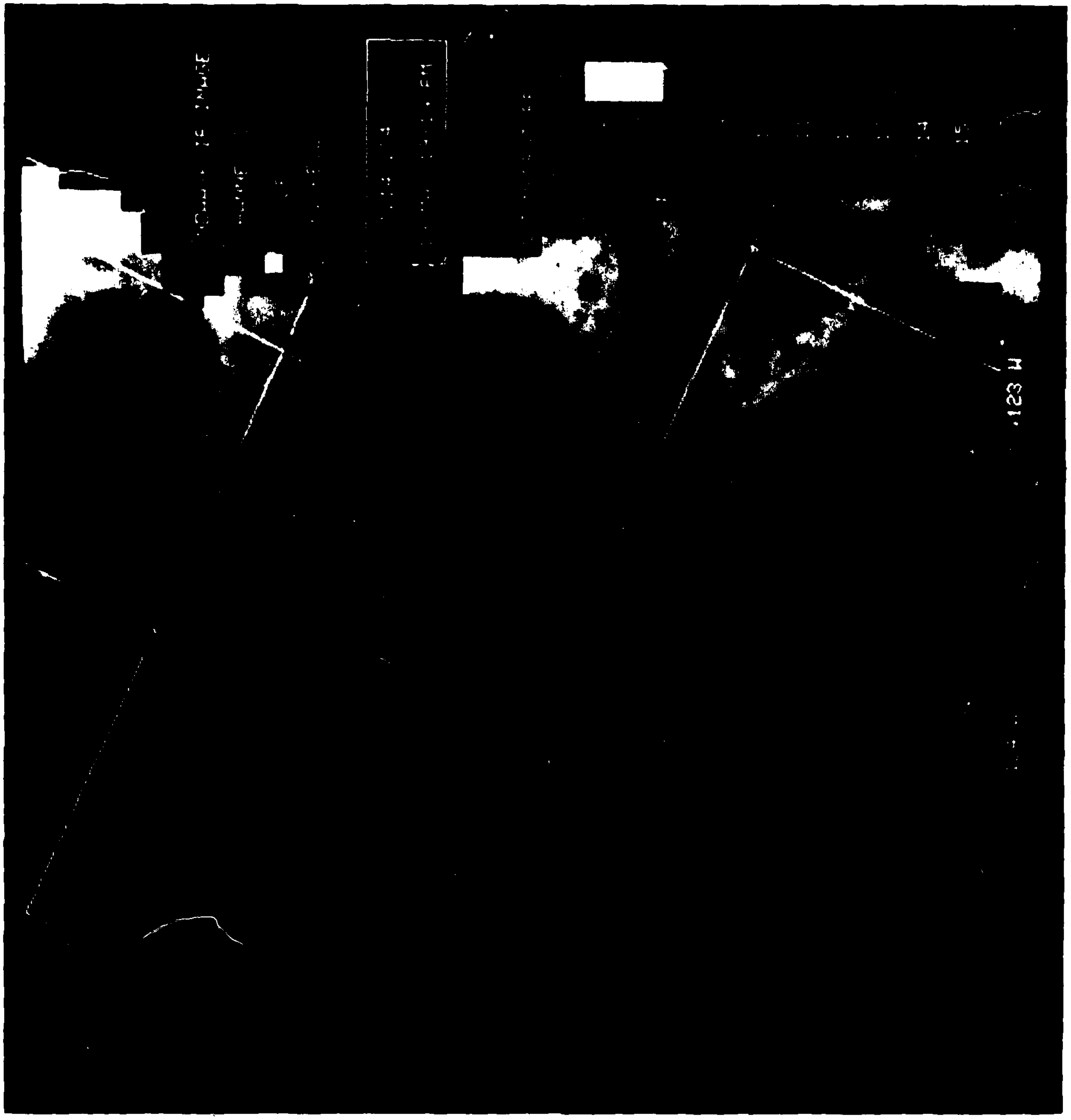

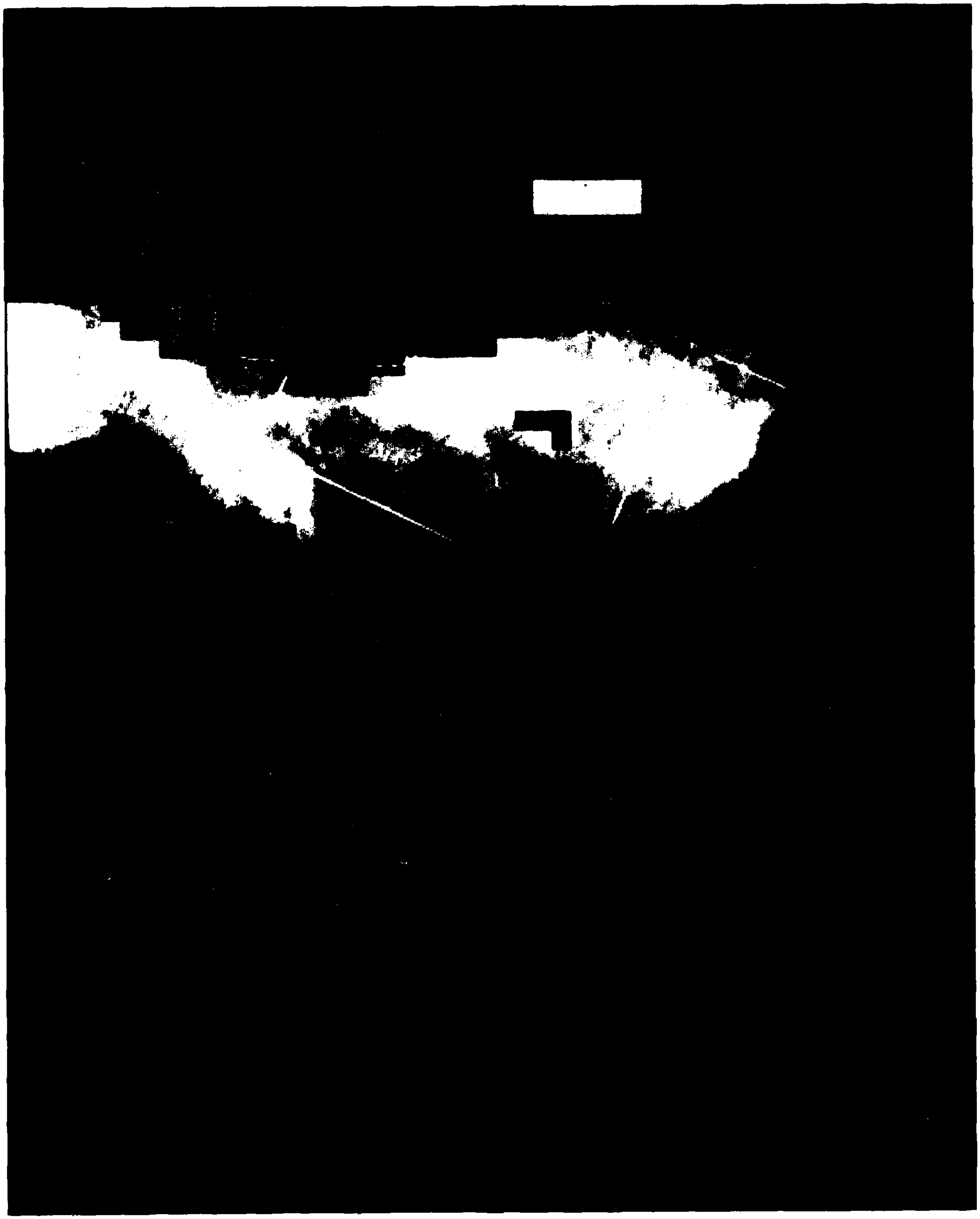

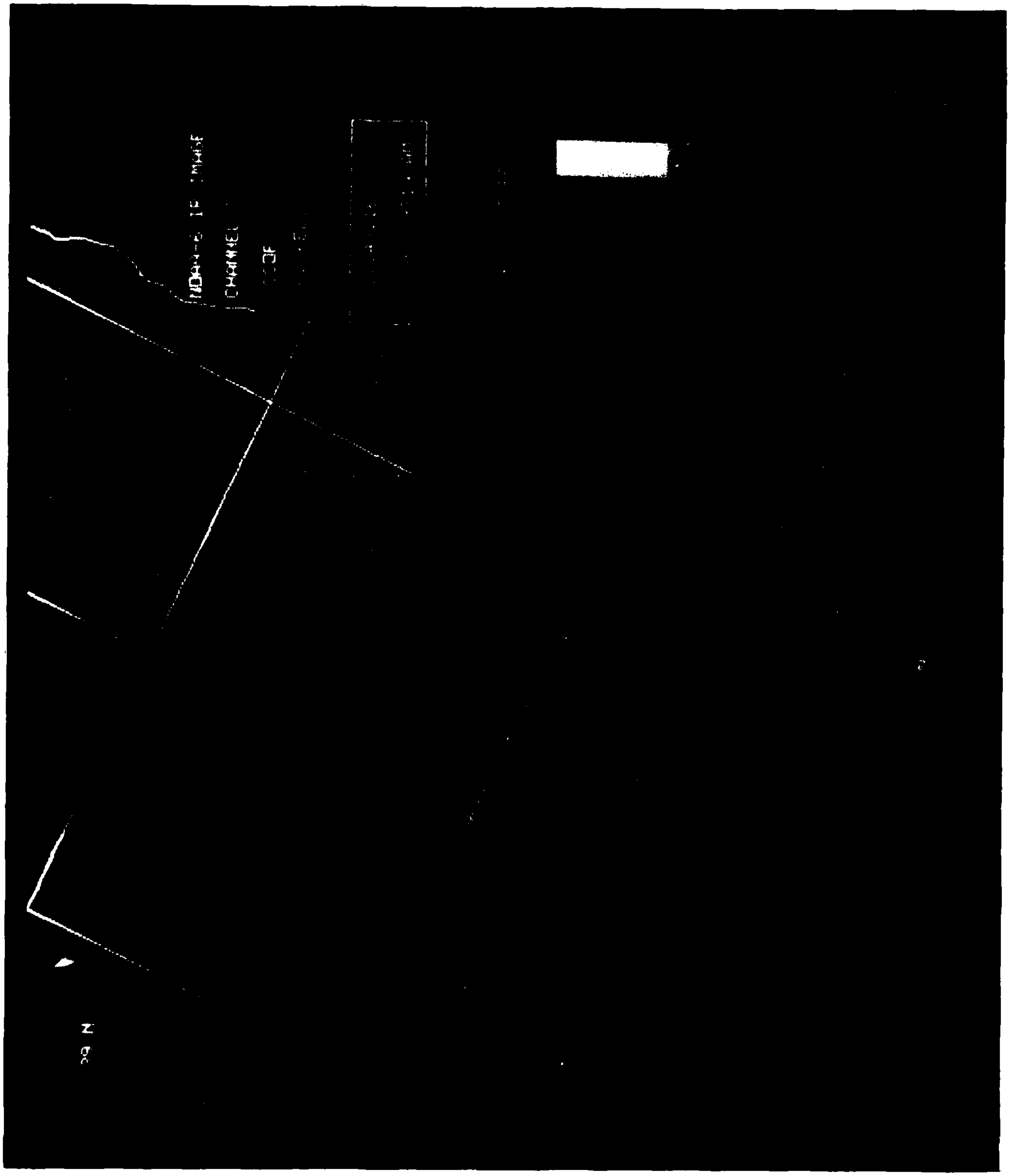
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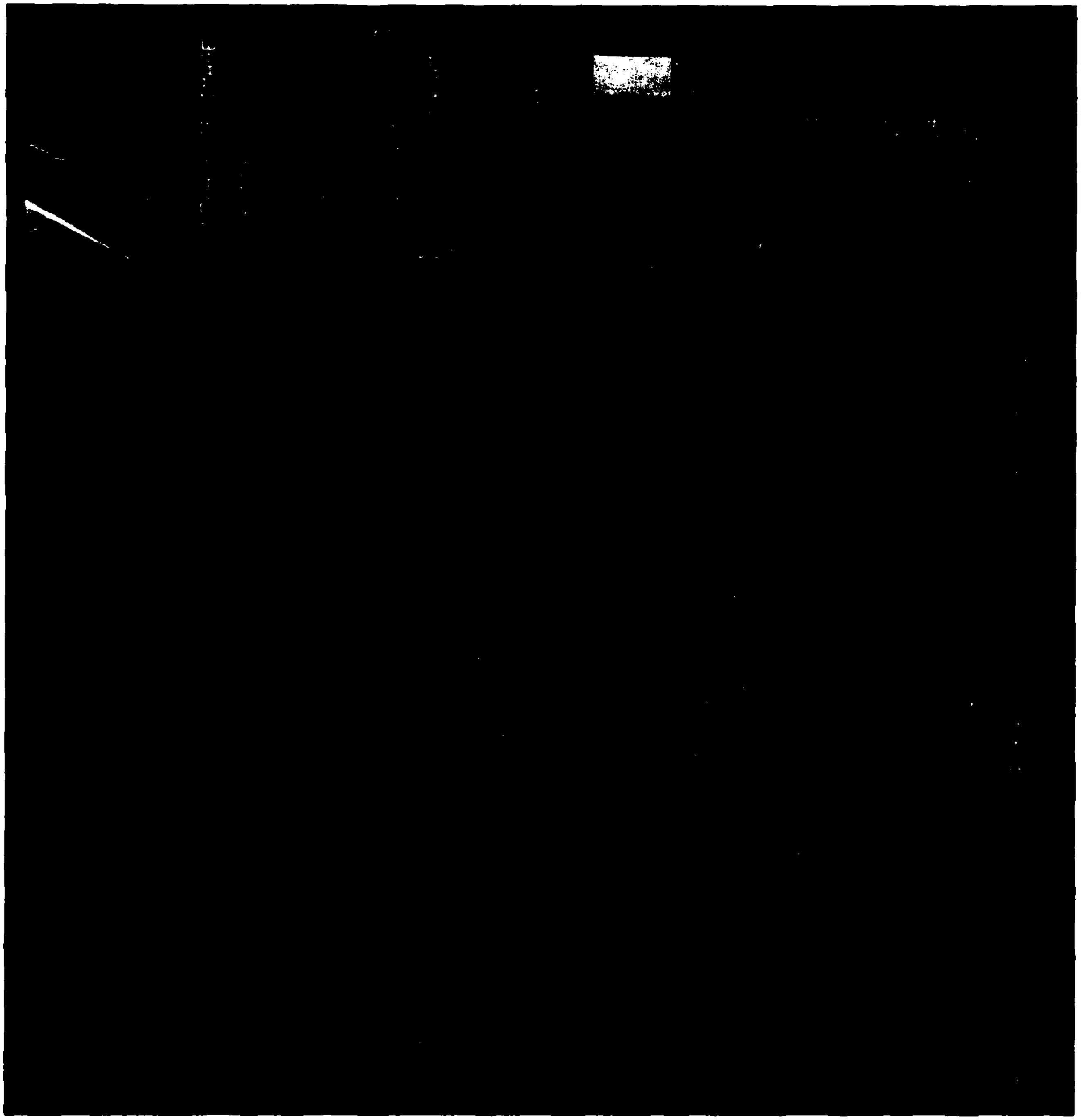

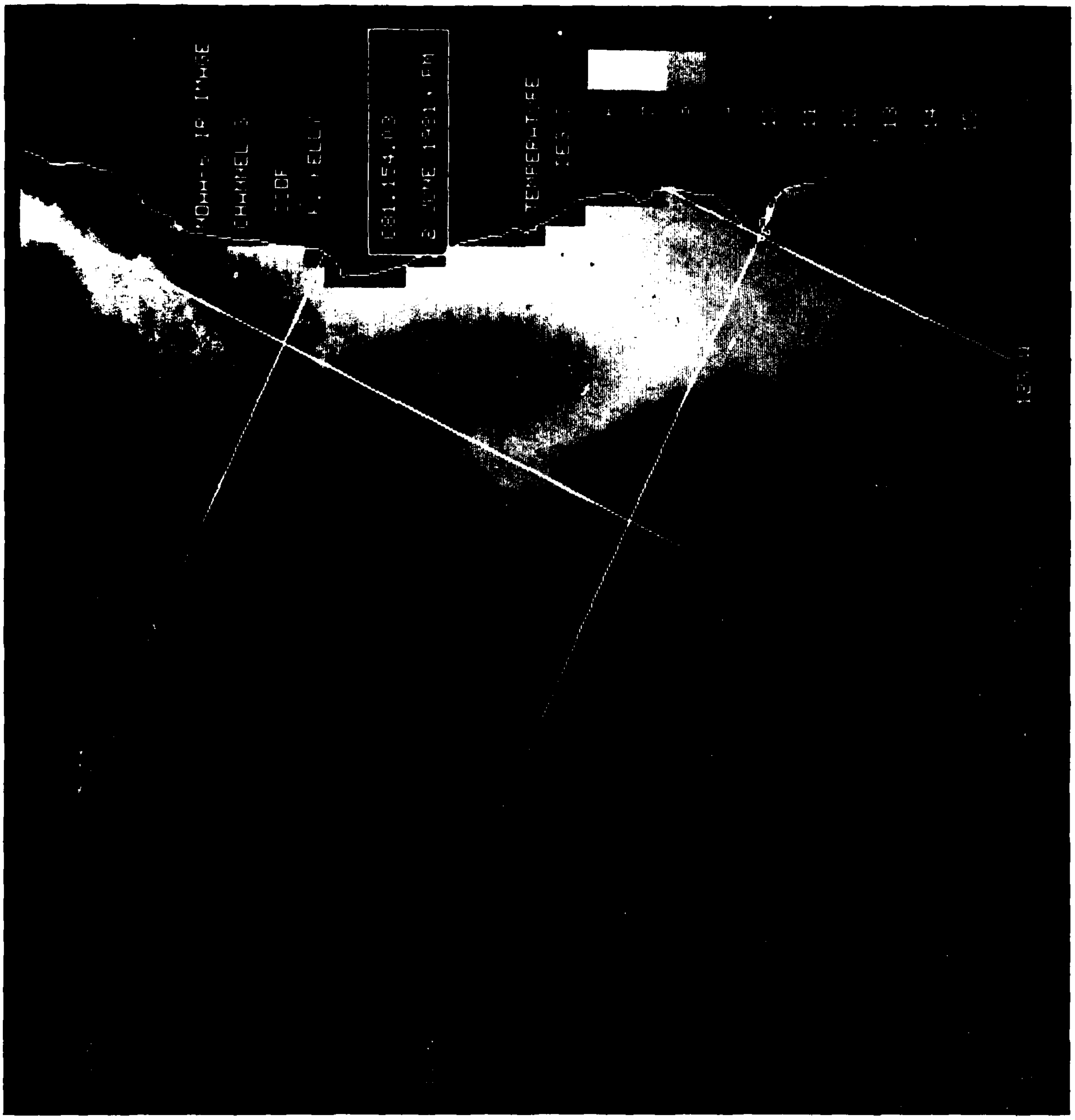
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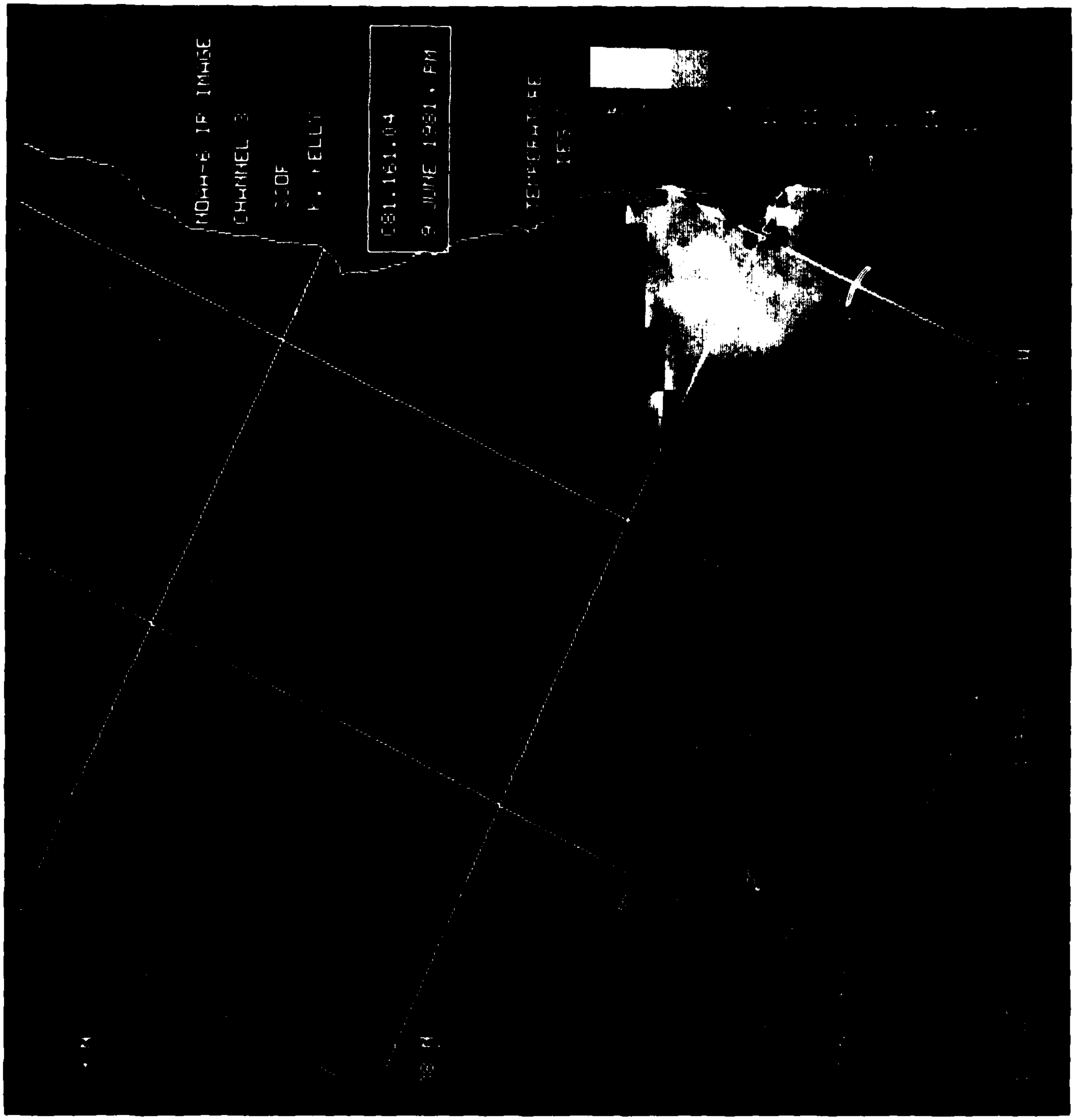
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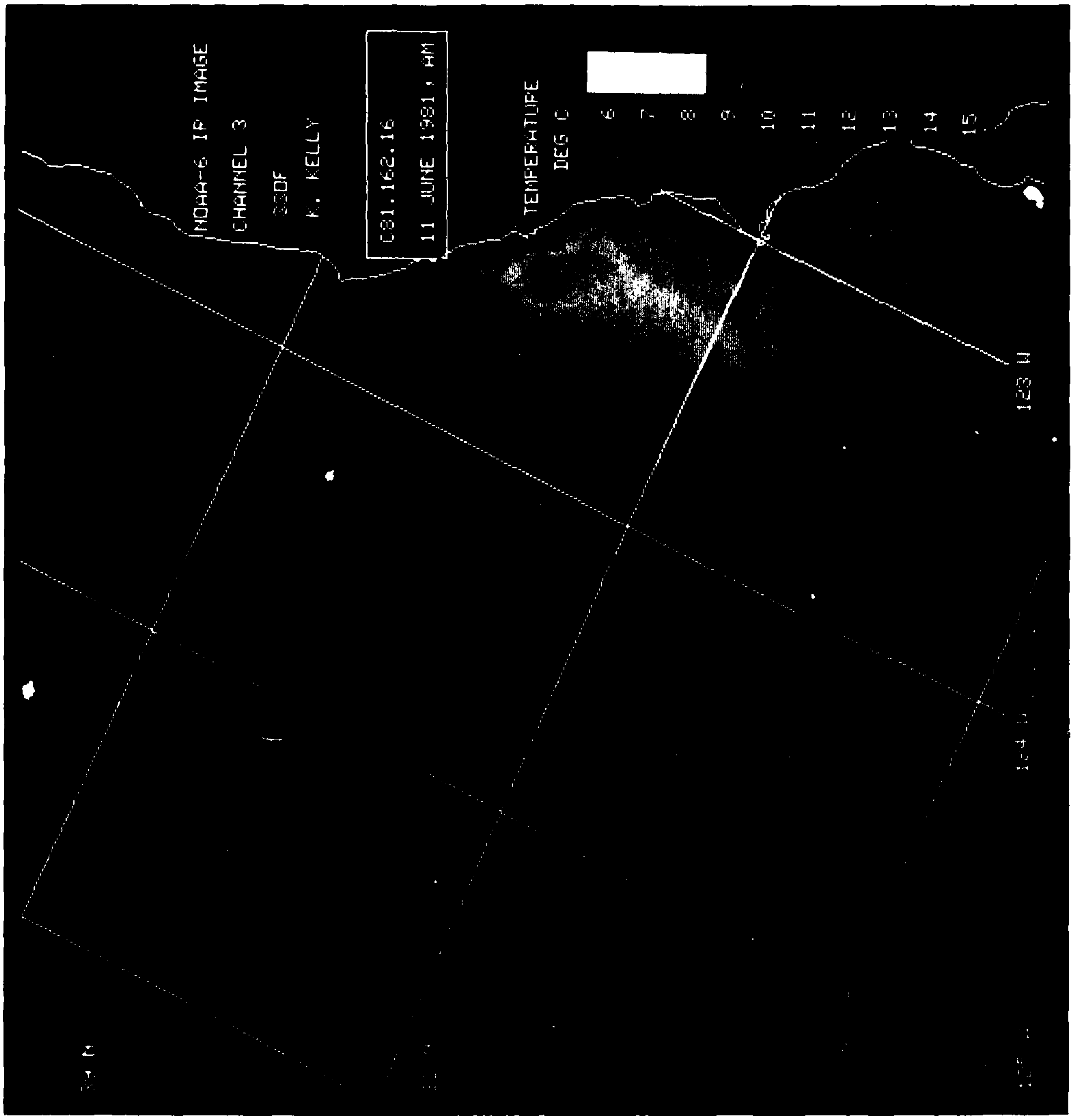
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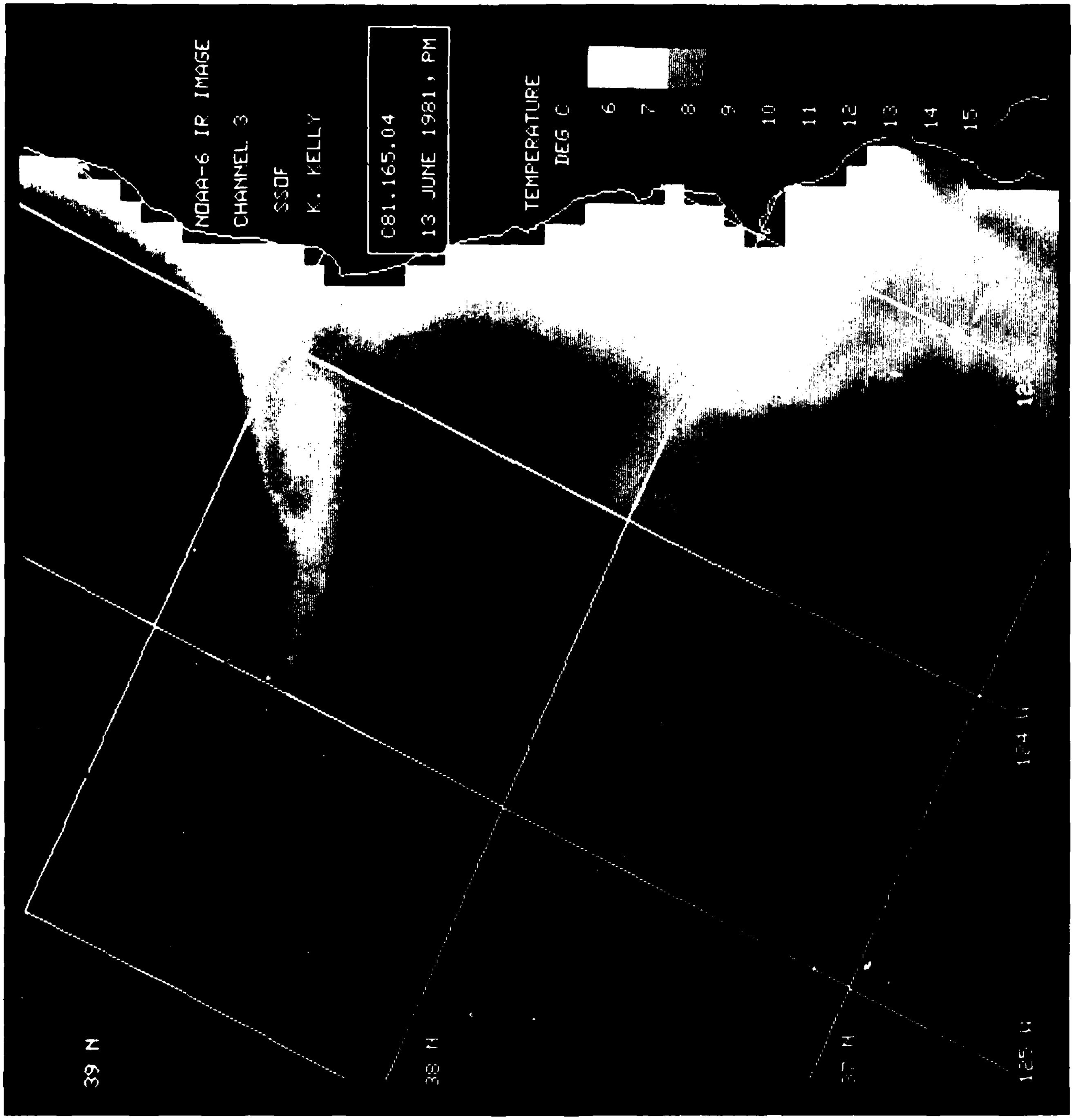
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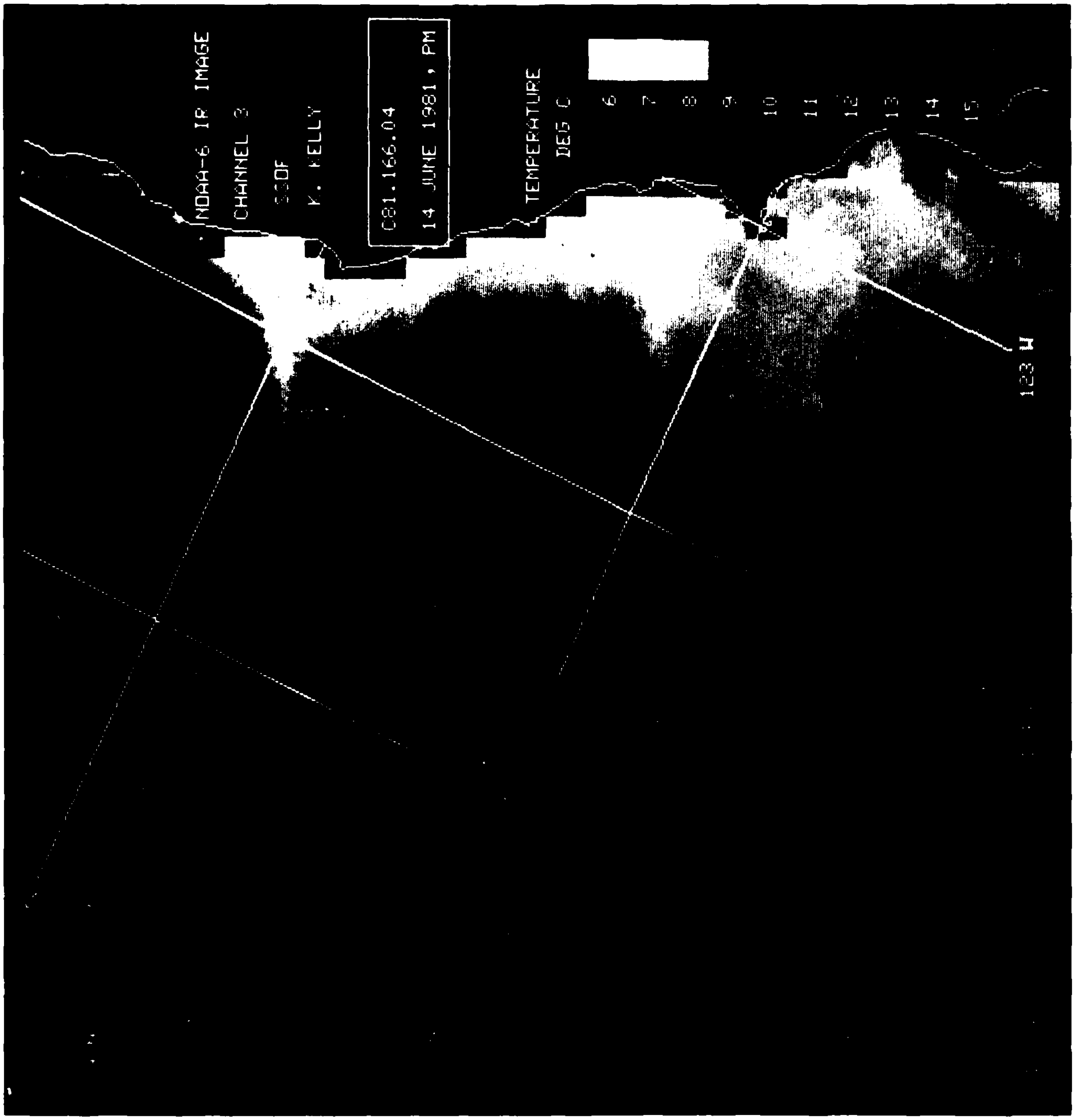
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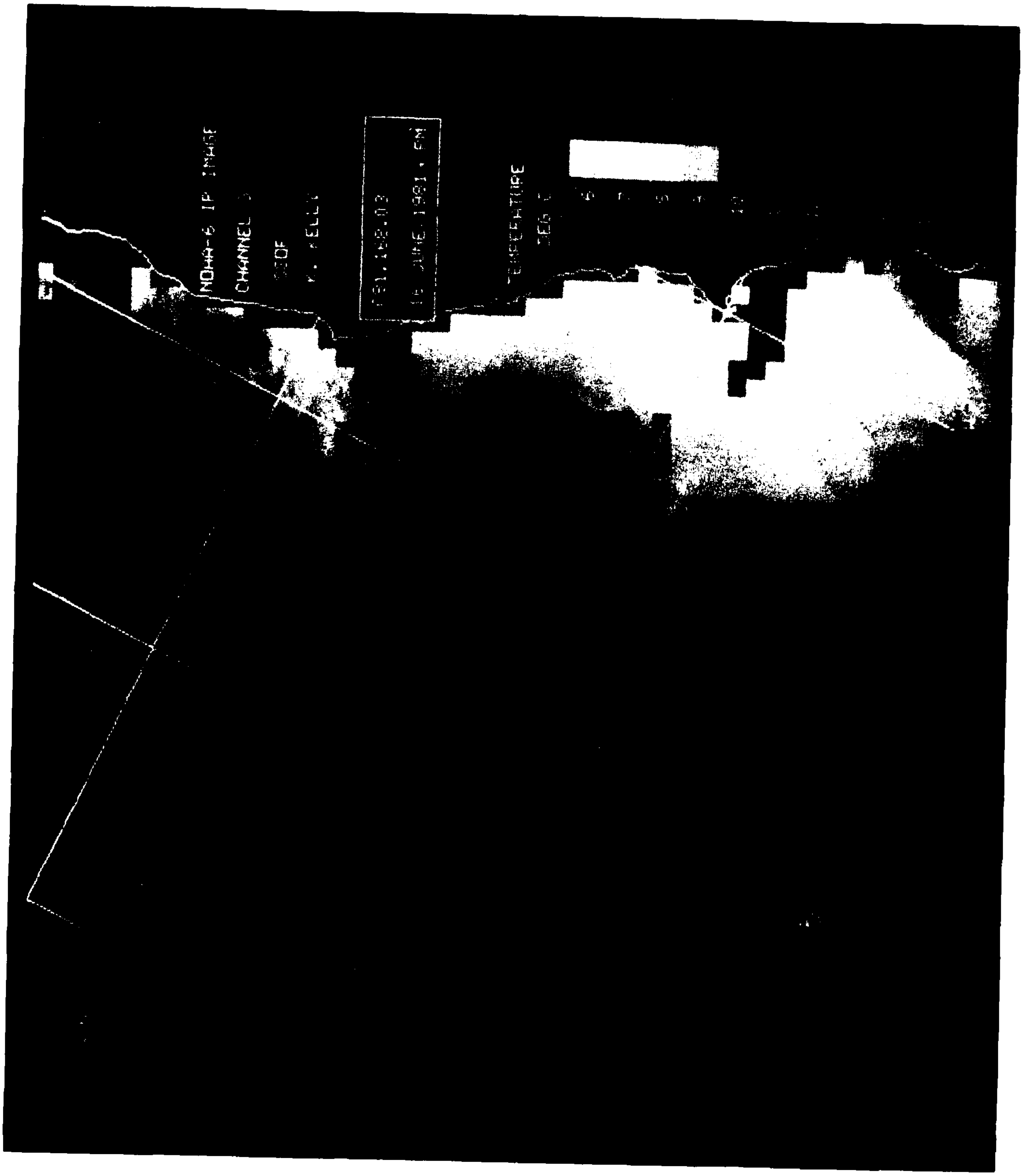
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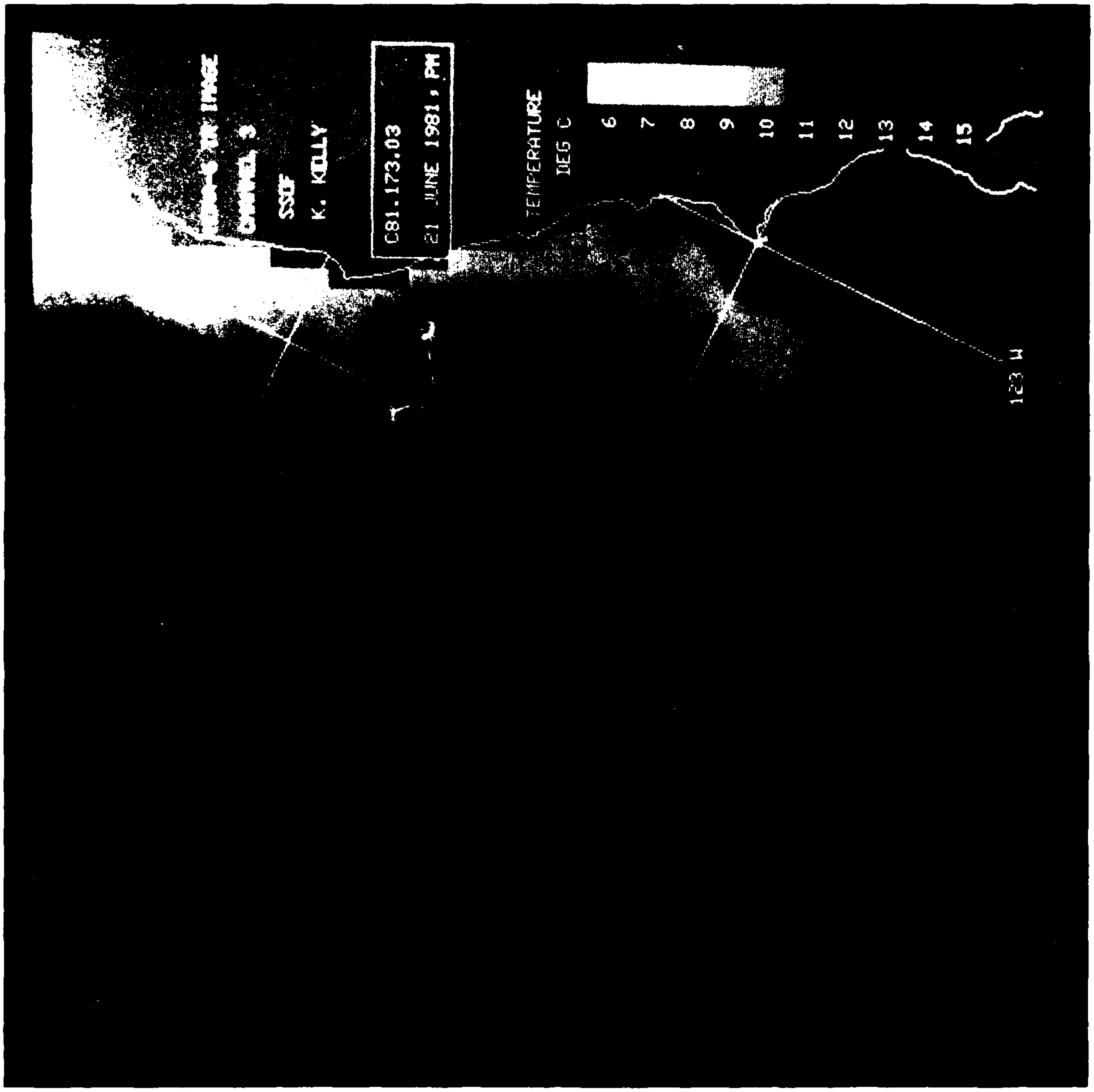
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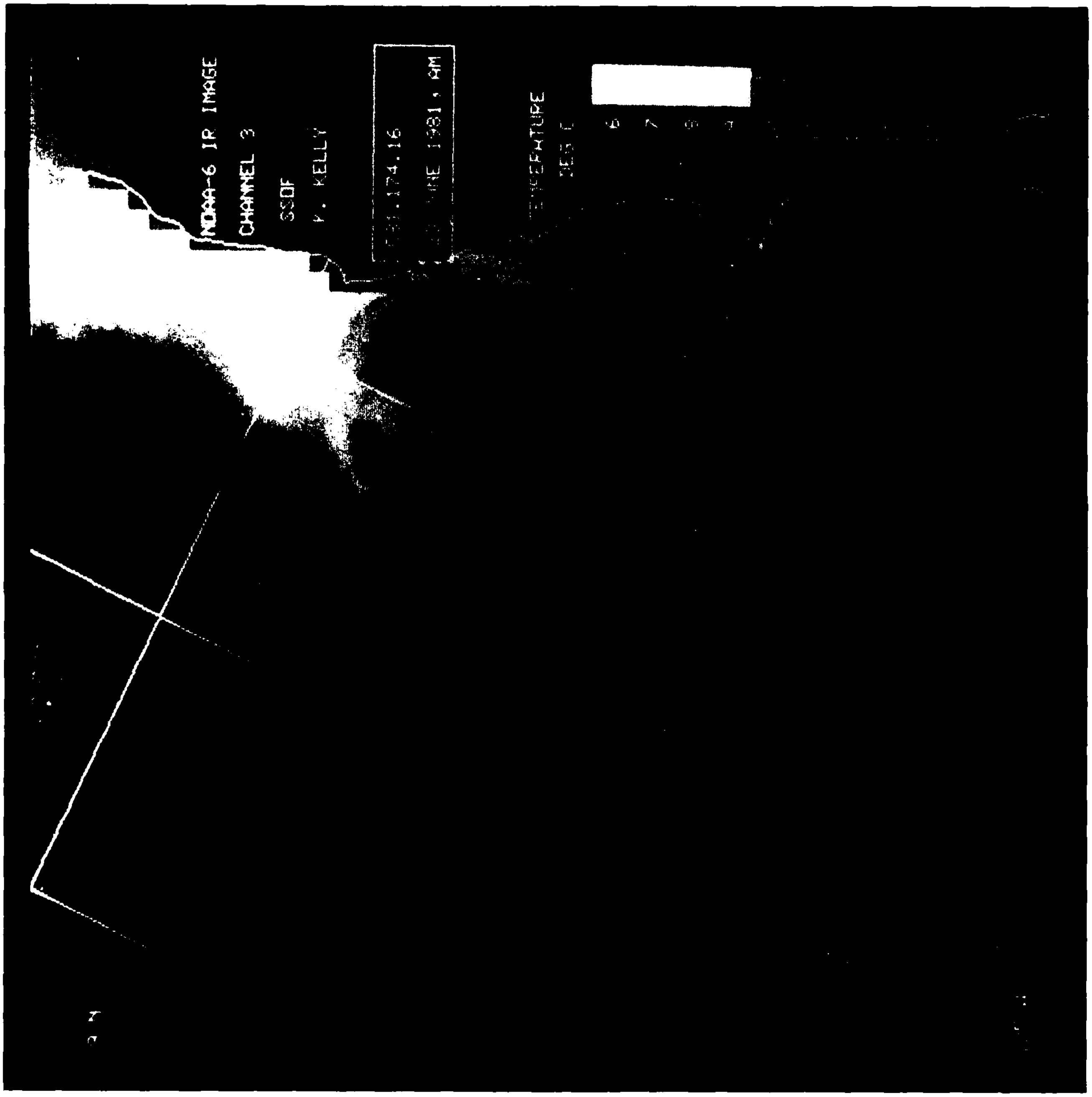
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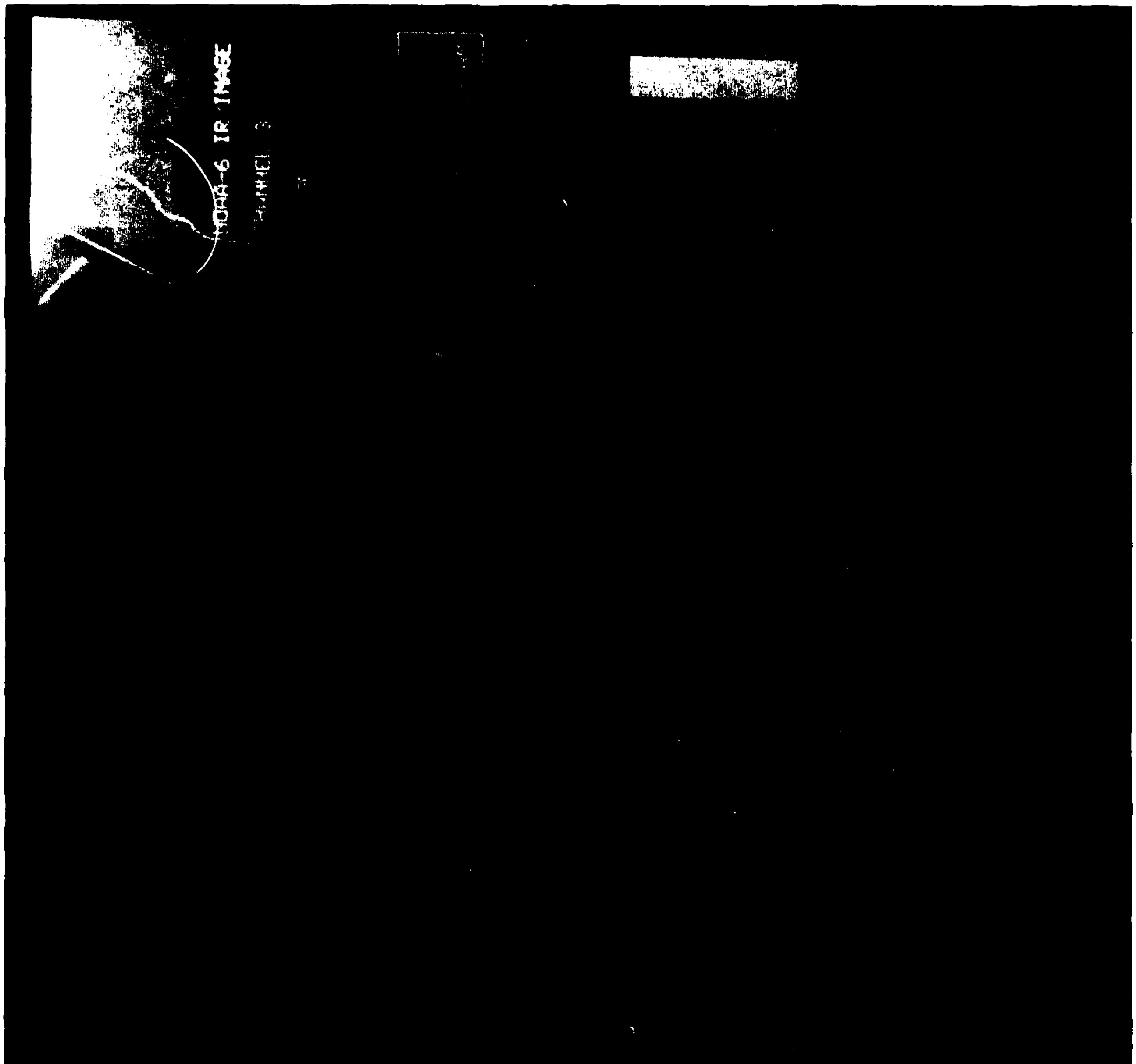
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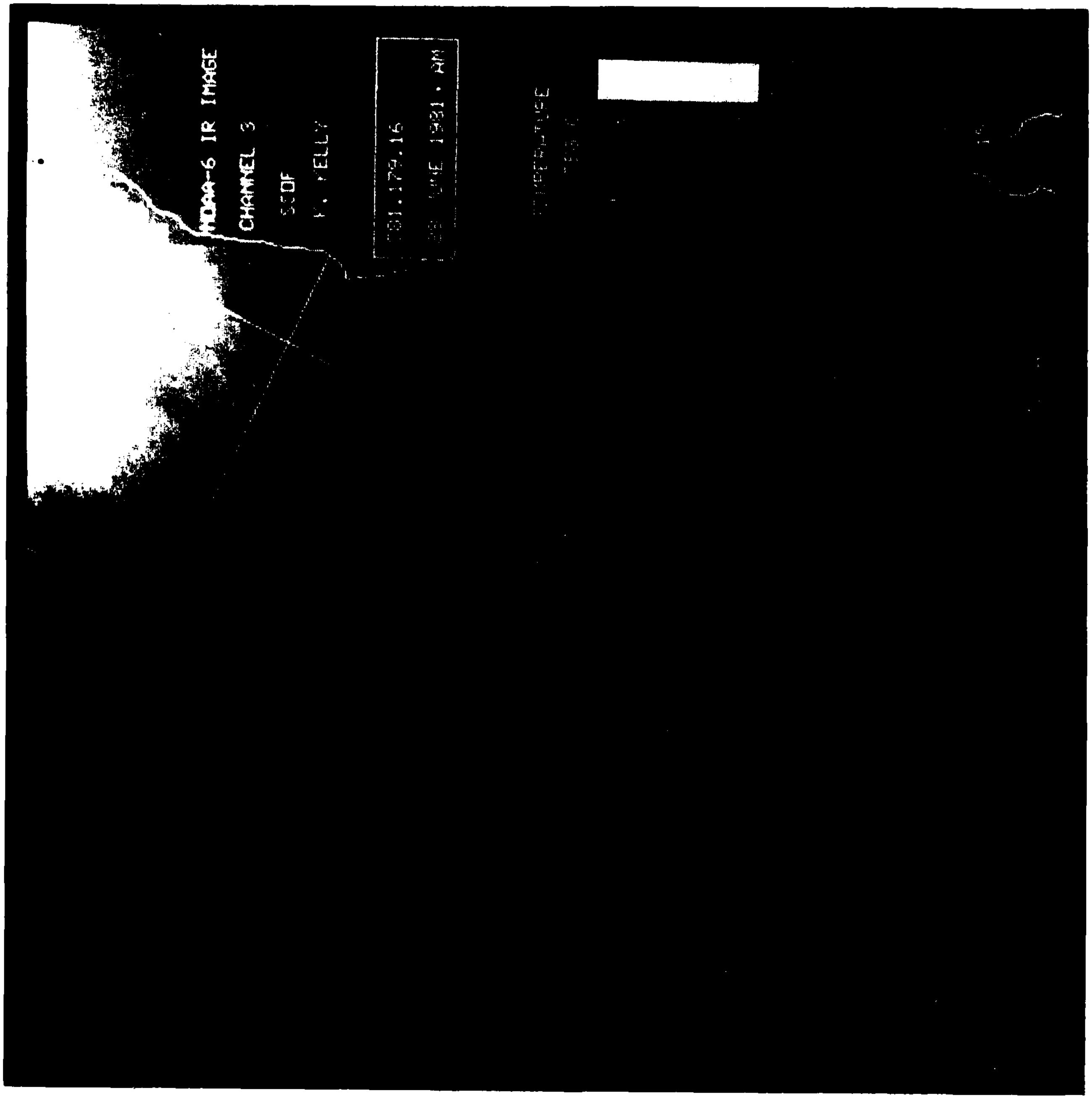
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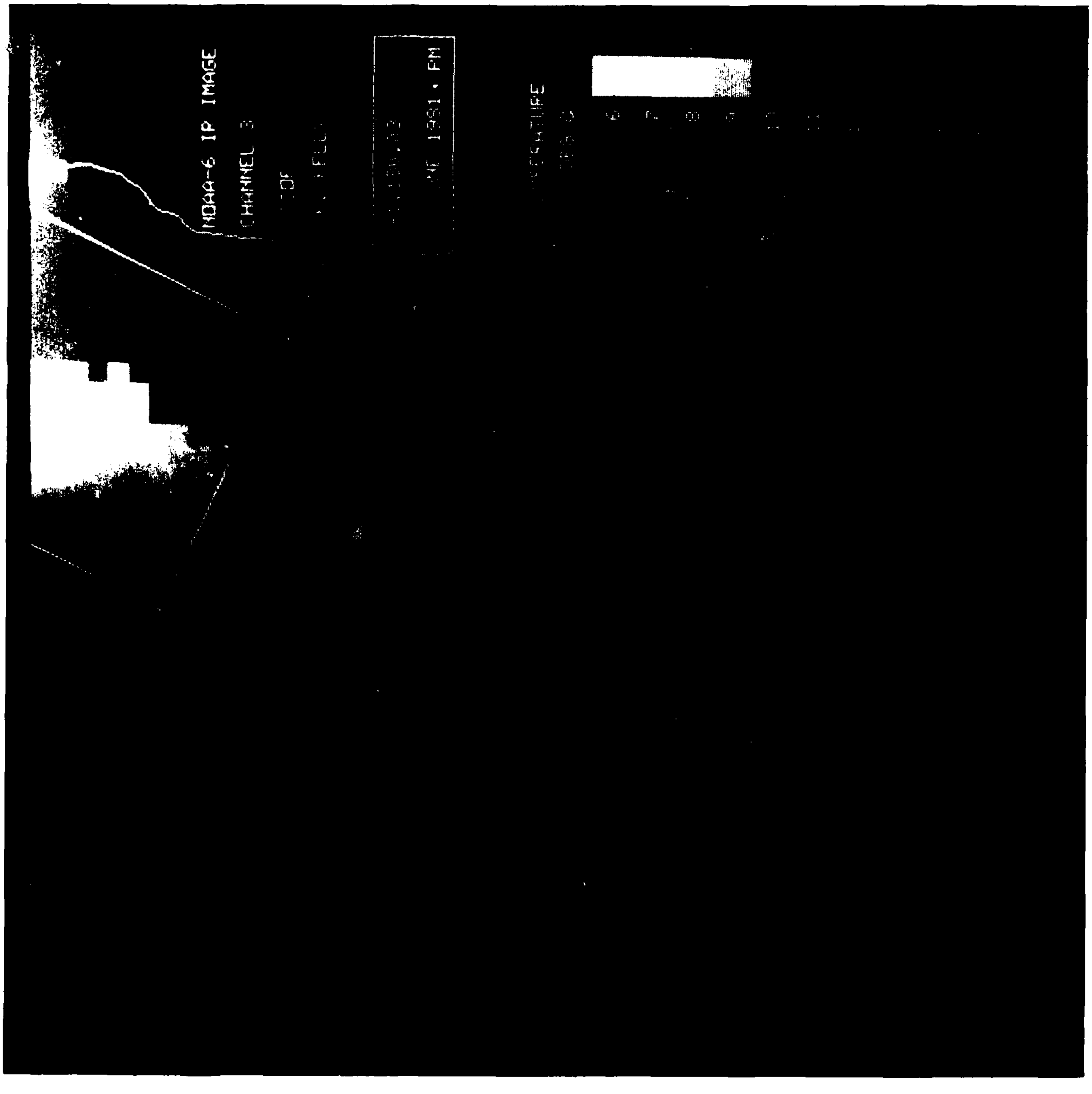
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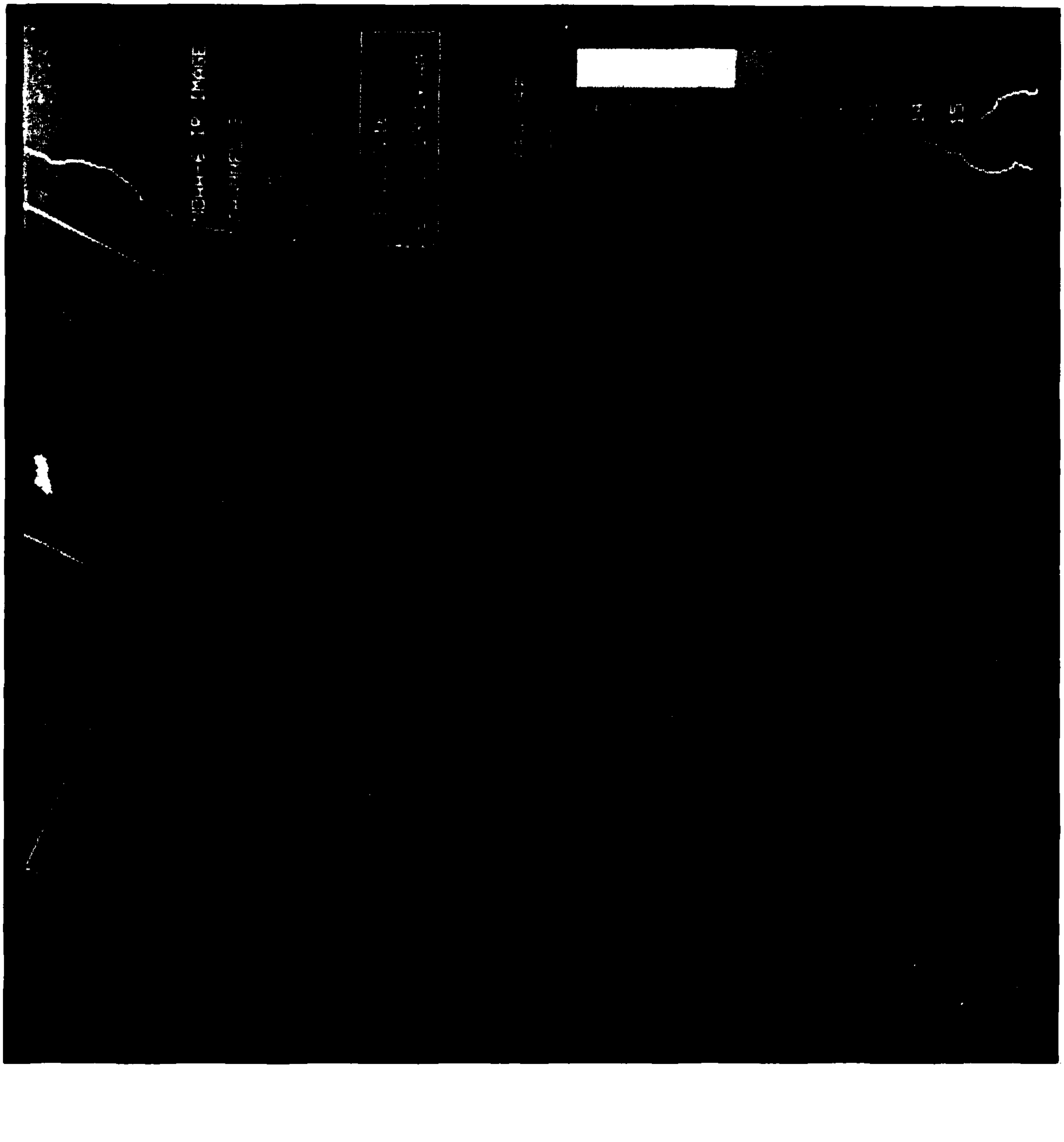

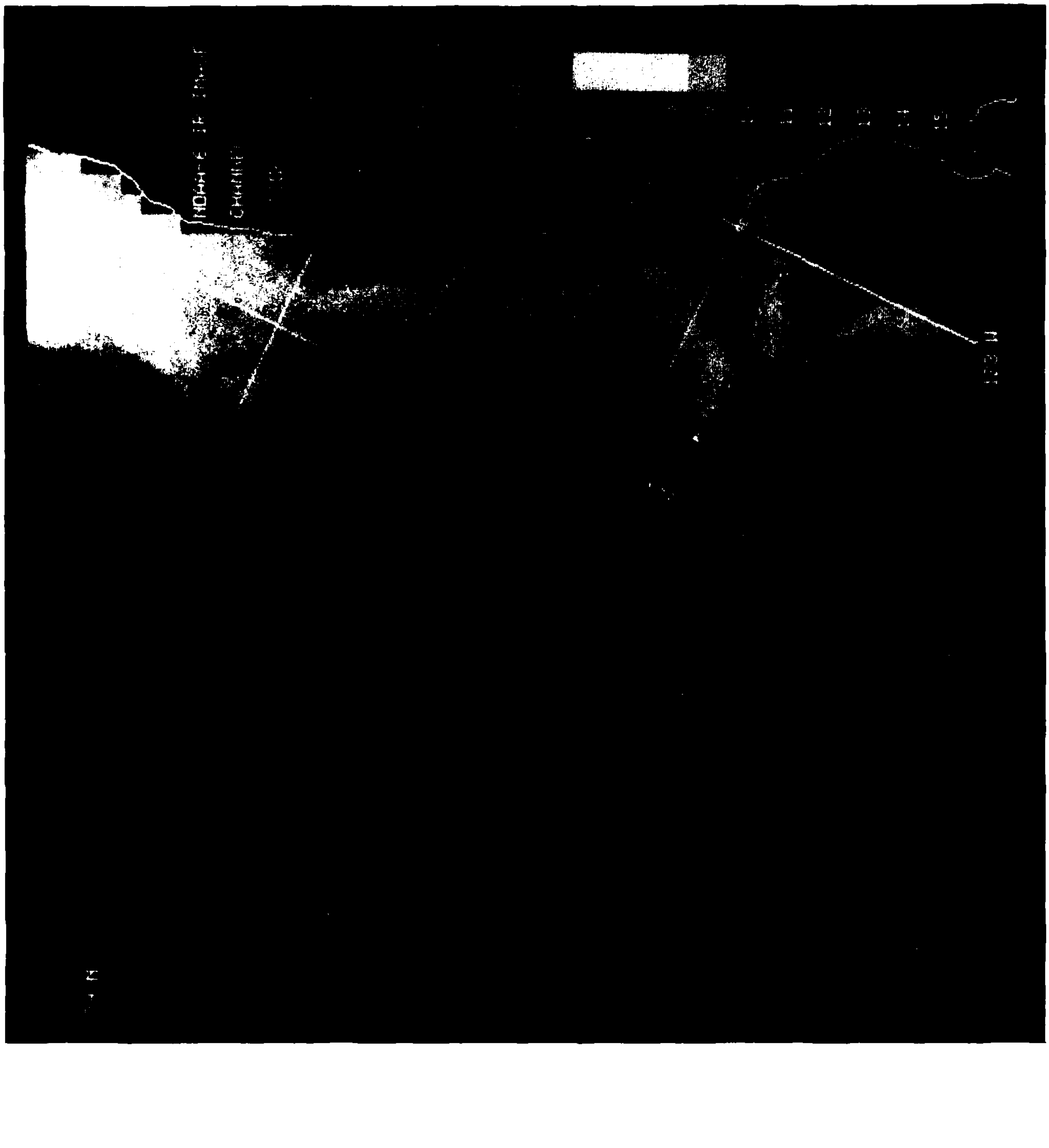

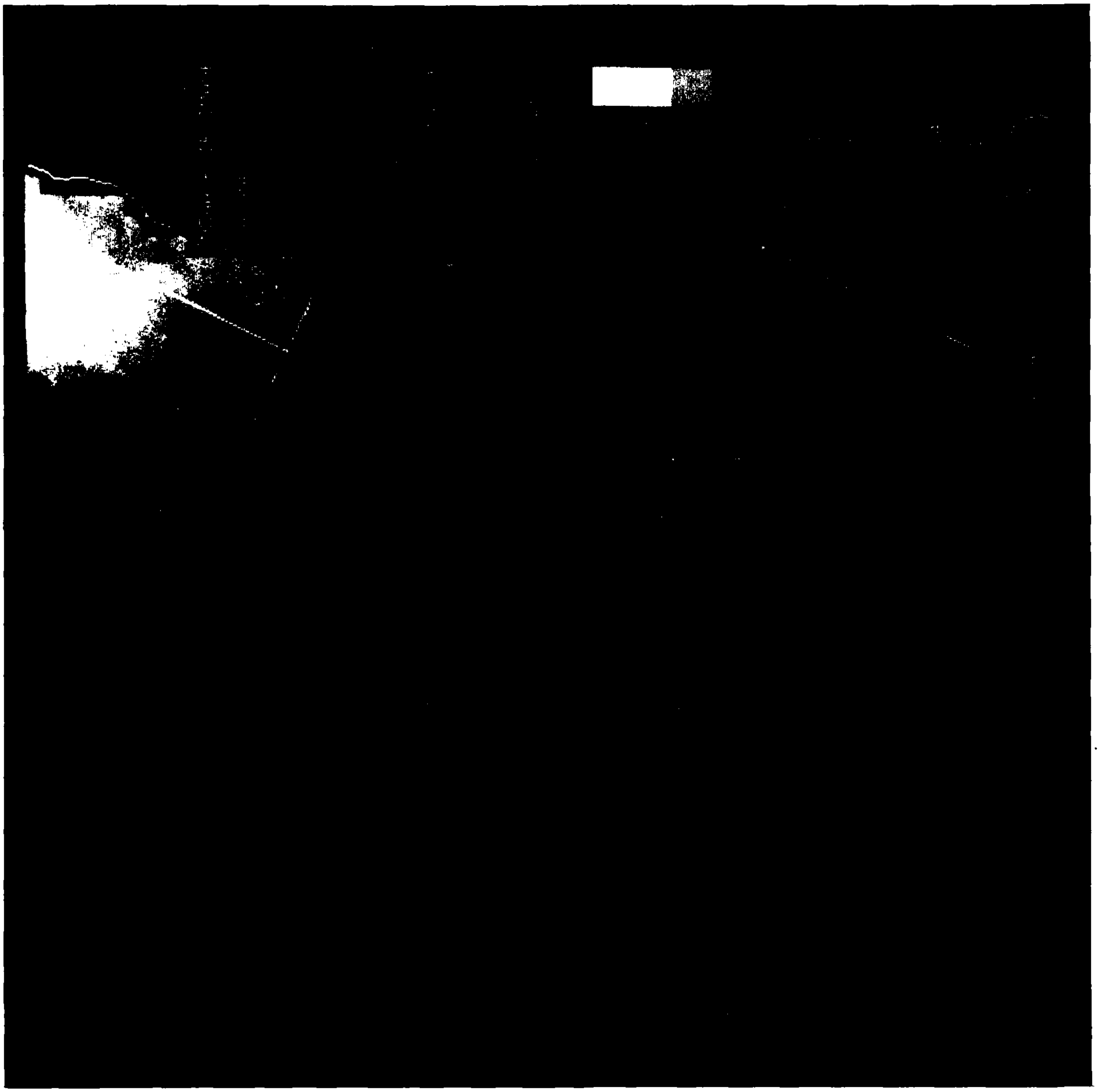

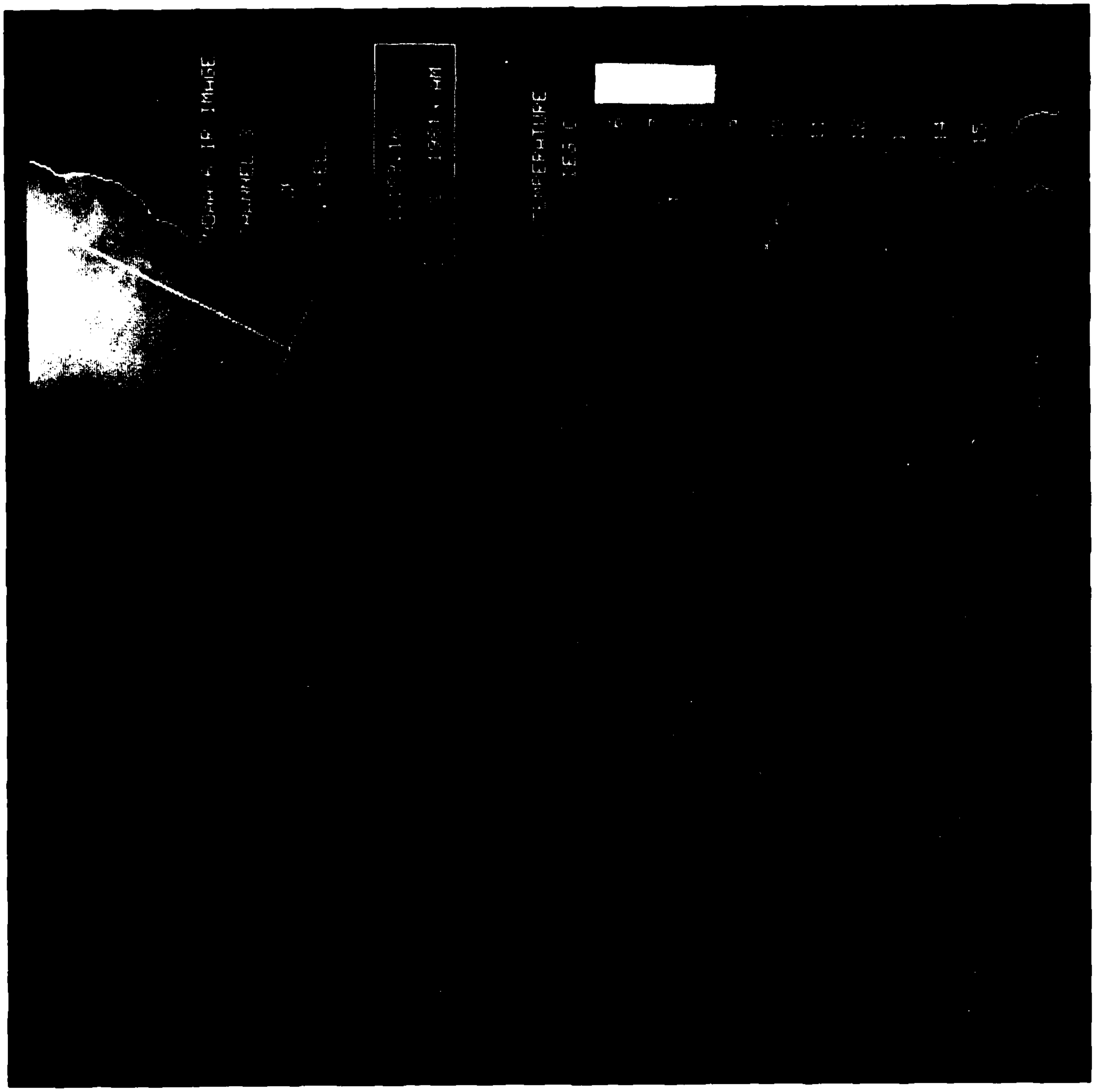

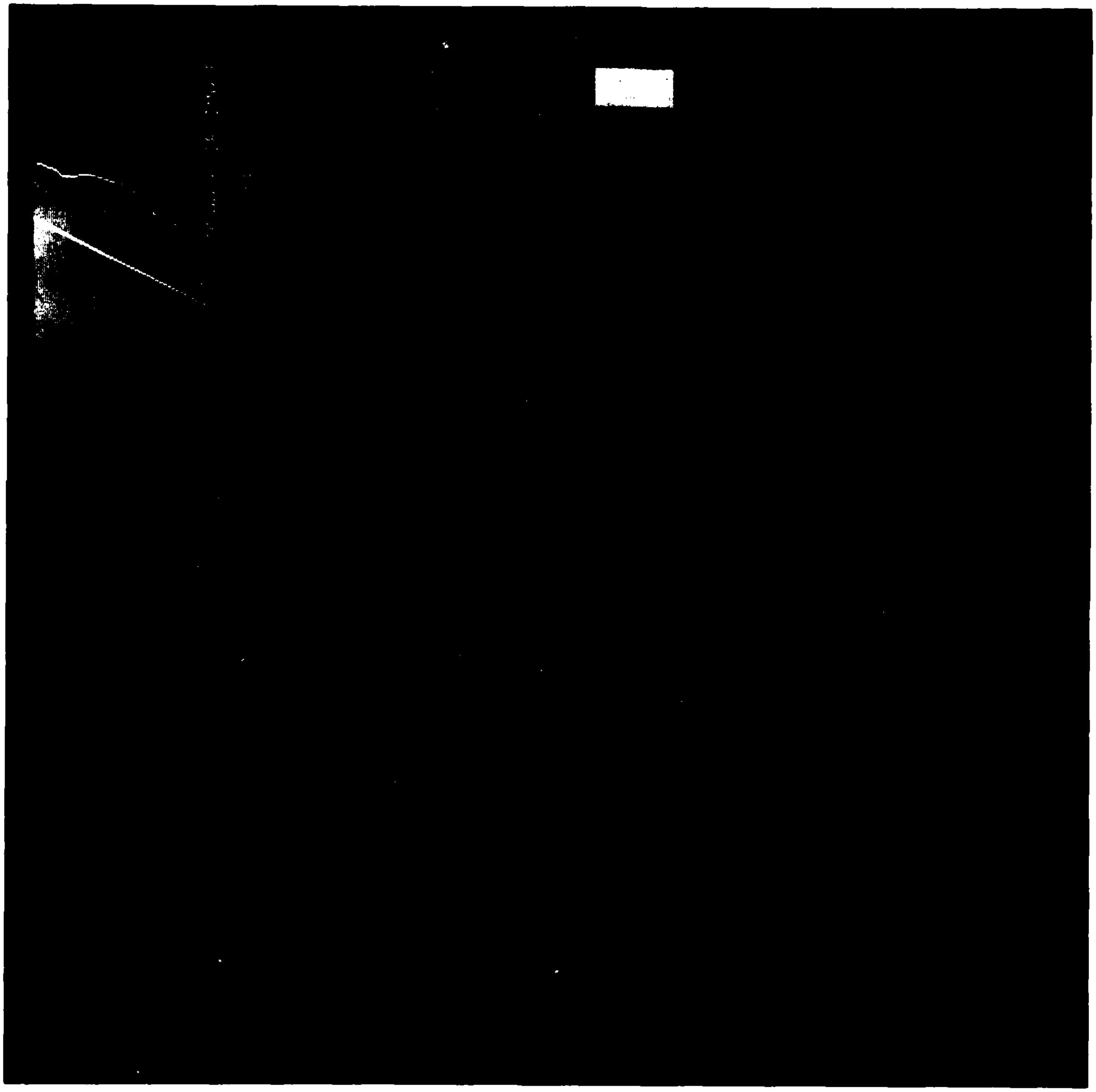

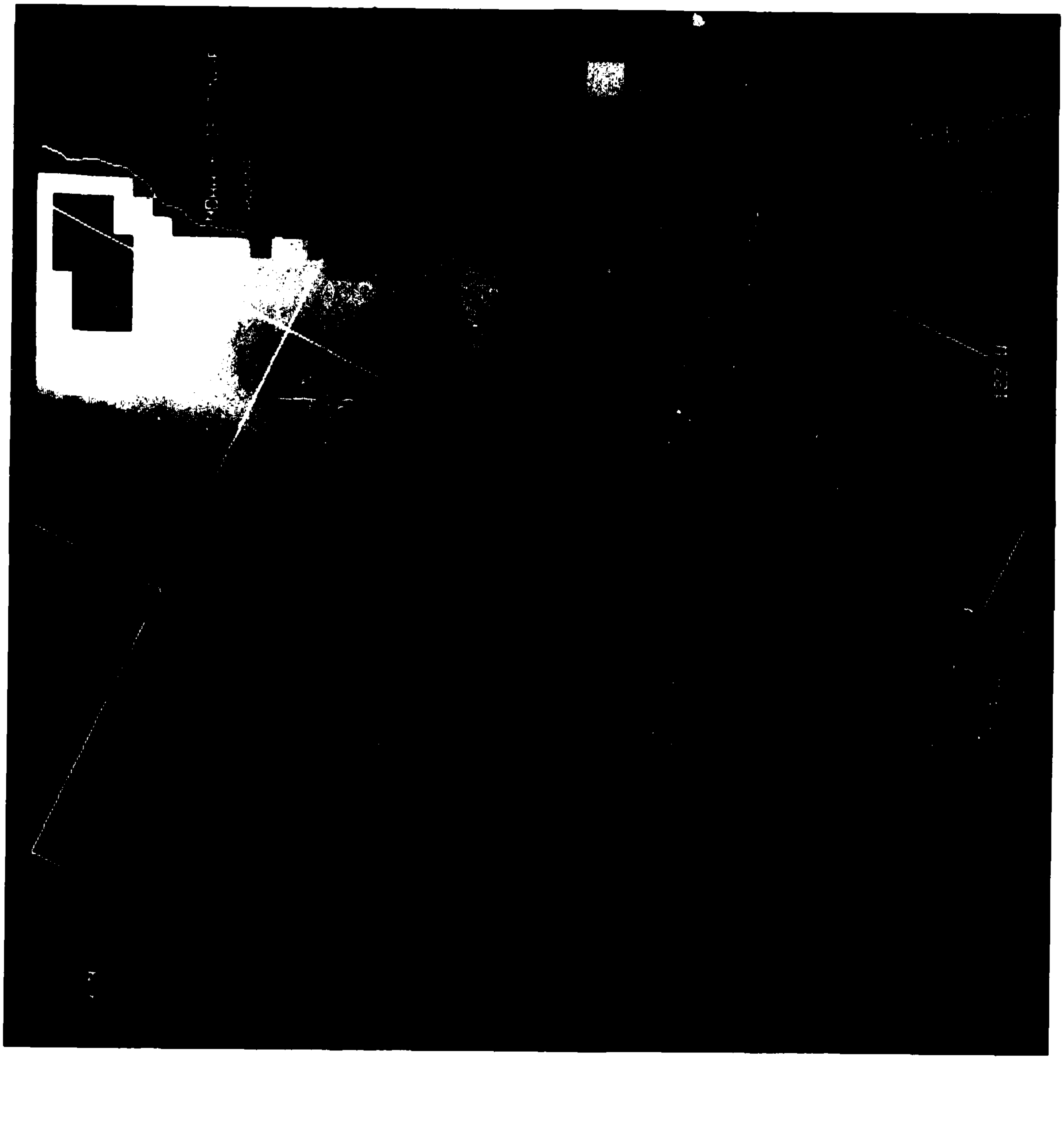

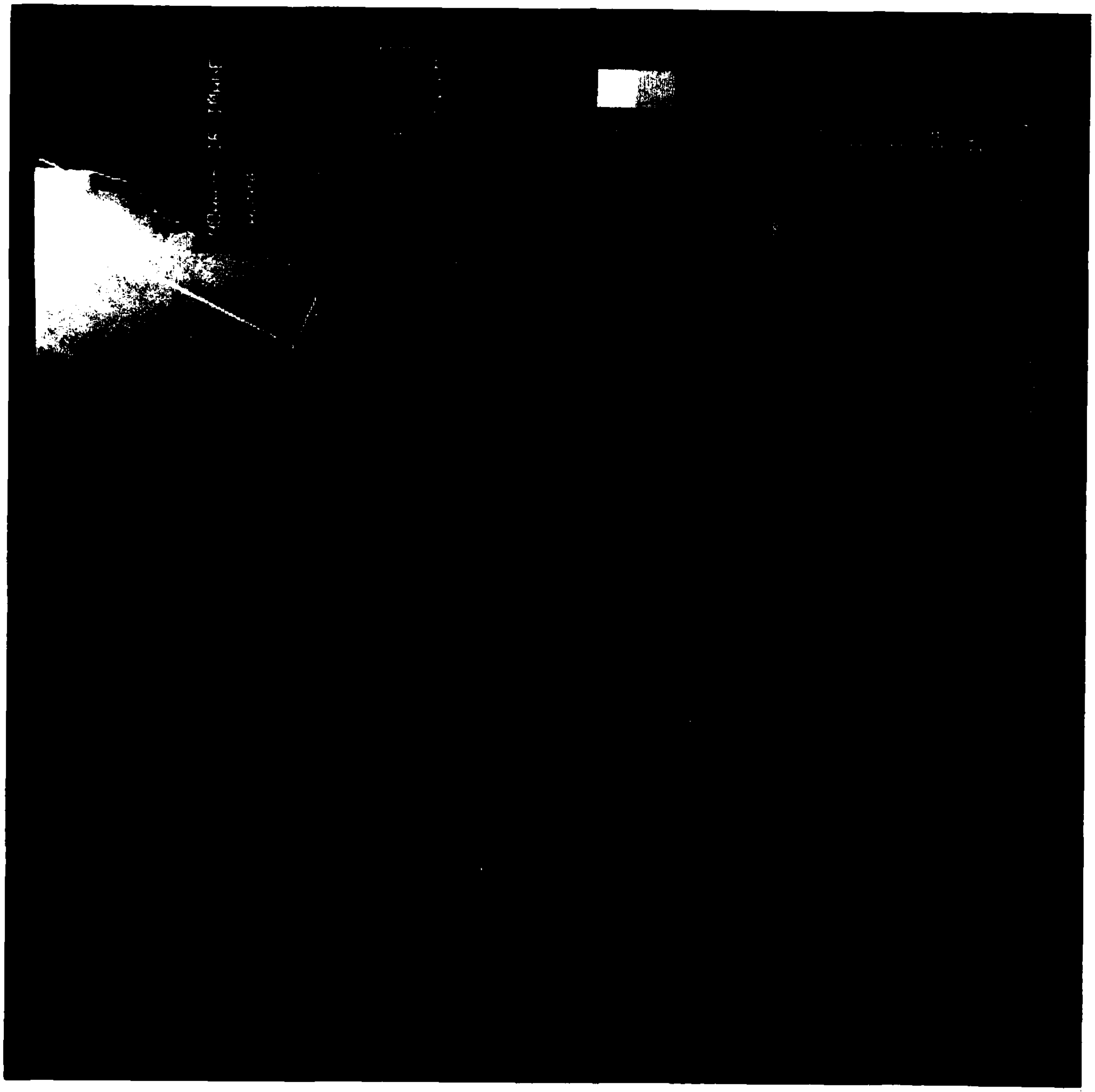


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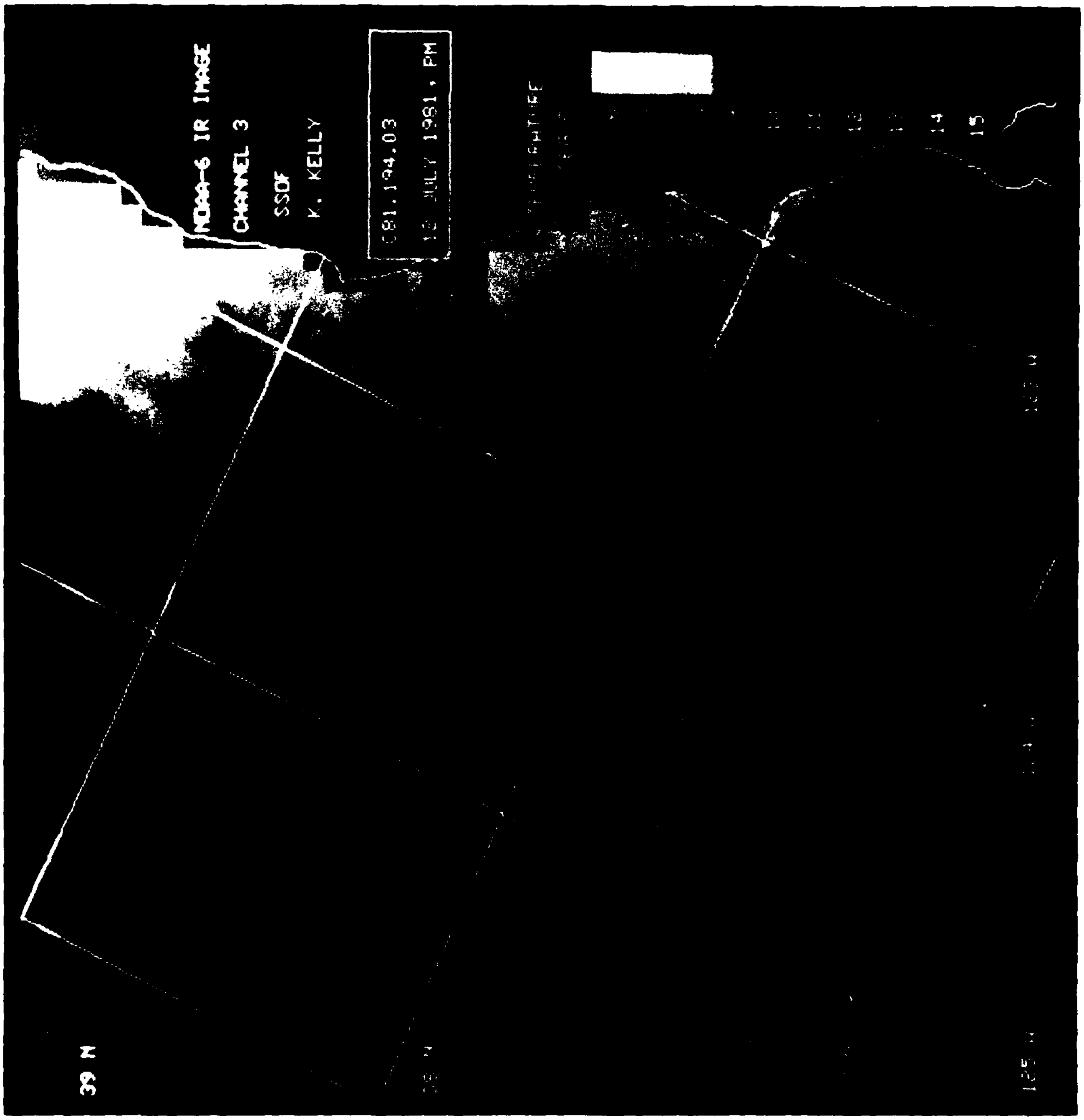
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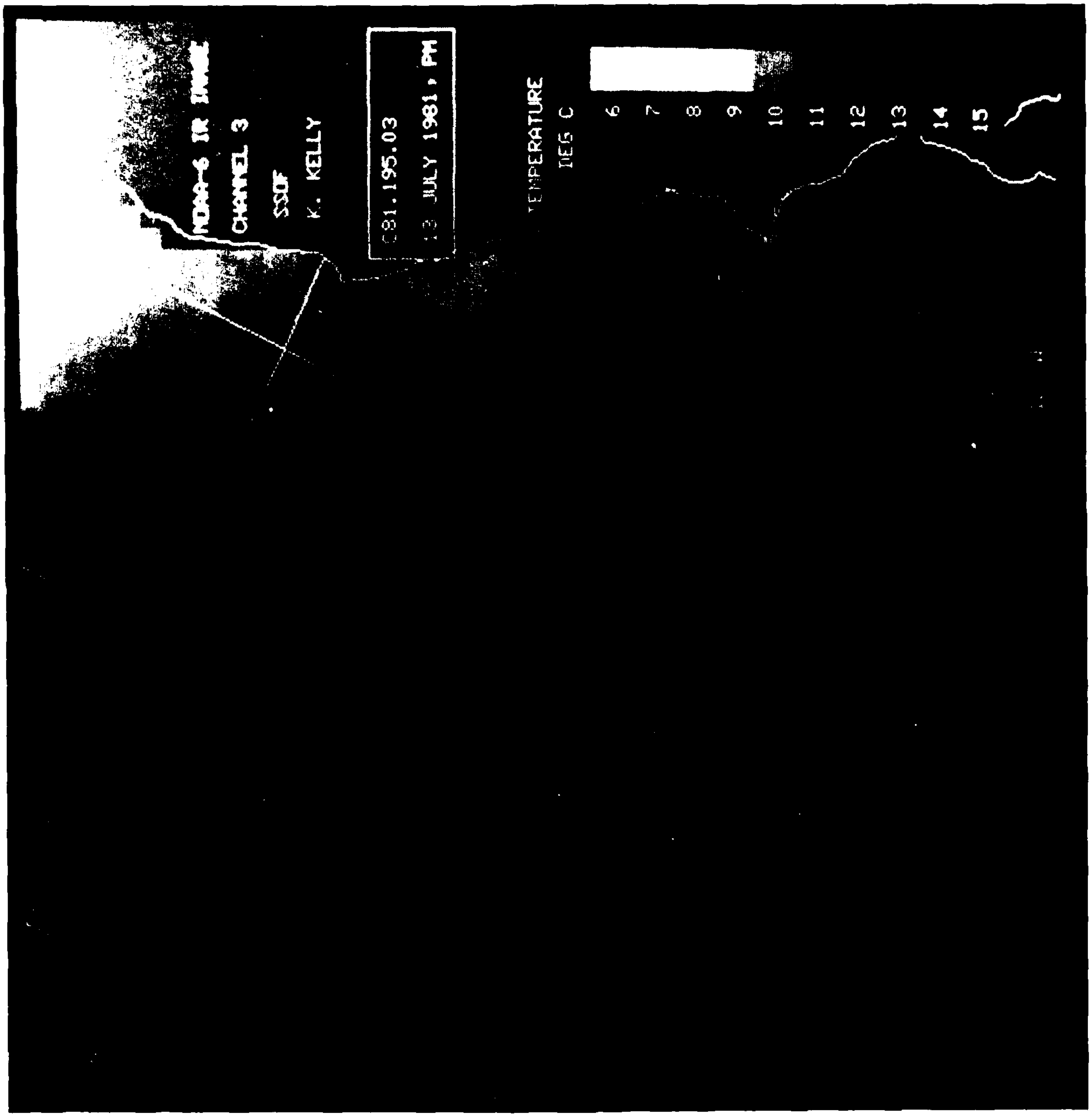
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K. KELLY
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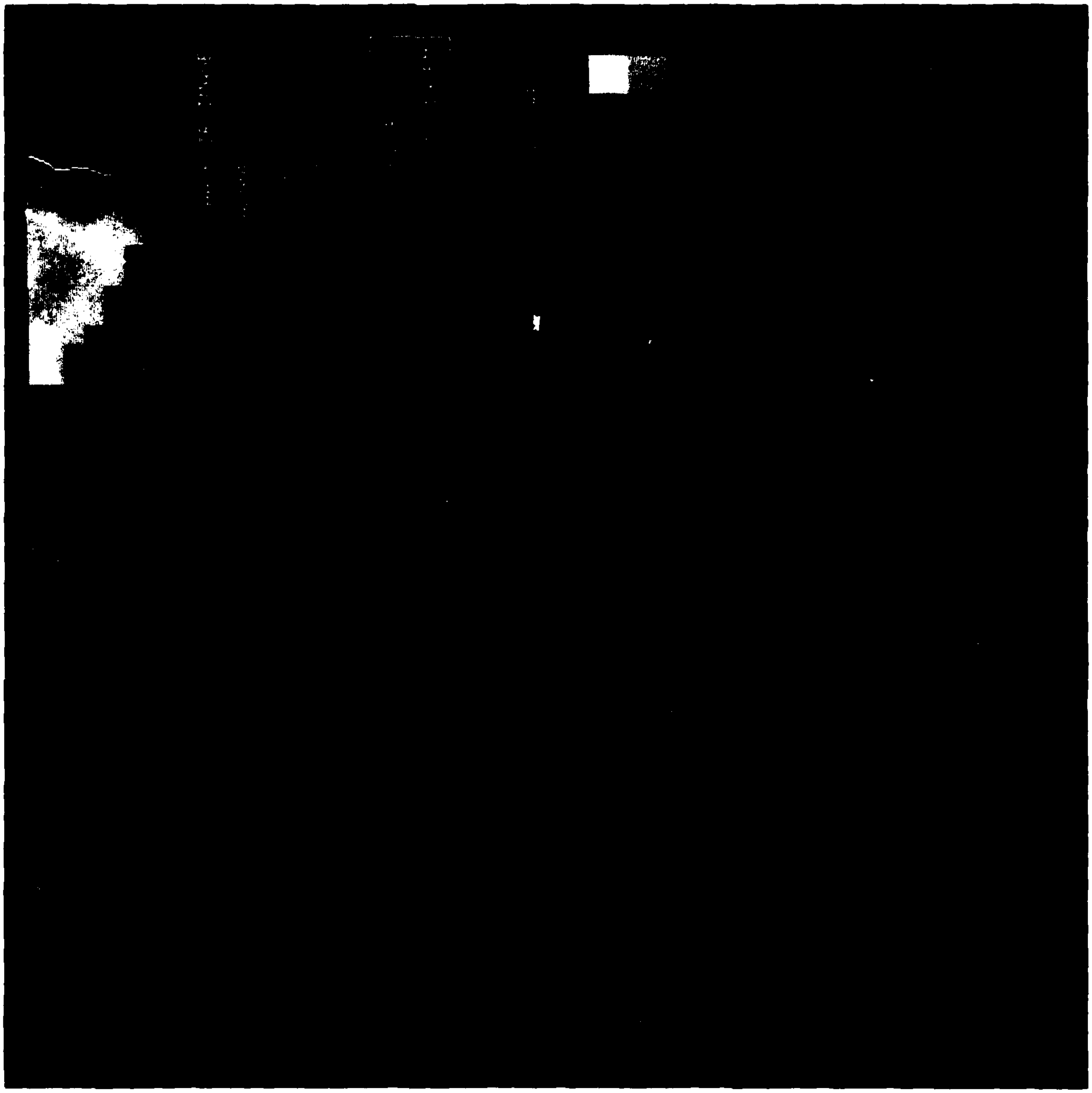

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